Remote sensing of fires with Meteosat

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IMAGES
REAL-TIME IMAGES
IMAGE LIBRARY
IMAGE GLOSSARY

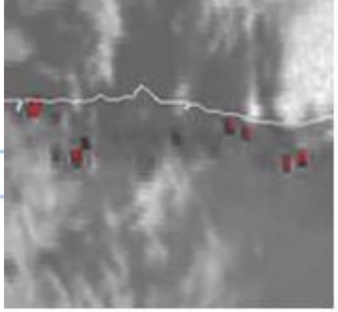
FILTER BY

Feature

Fire

- Drought
- Dust
- Equinox
- Extratropical transition
- Fire
- Flood
- Foehn
- Fog
- Front
- Frost
- Gap Wind
- Gravity Wave
- Gust Front
- Haboob
- Hail
- Haze
- Heatwave
- Hot Spot
- HRV Winds
- Humidity

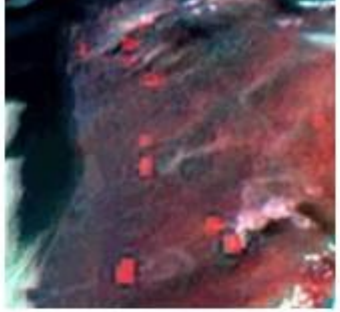
APPLY RESET



FIRES DEVASTATE PARTS OF ASTURIAS AND CANTABRIA

19 December 2015

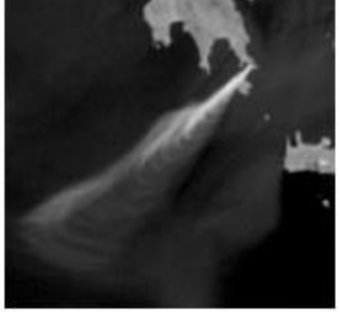
Northern regions of Asturias and Cantabria in Spain were ravaged by hundreds of fires in December.



FIRES IN THE IBERIAN PENINSULA

06 August 2015

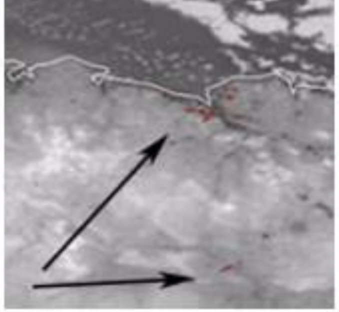
Due to the hot summer and consequent dry soil, there were a number of fires in the Iberian peninsula, on 6-11 August.



WILDFIRES IN GREECE

17 July 2015

In the night of 16/17 July wildfires broke out in the extreme south-eastern corner of the Peloponnese peninsula.

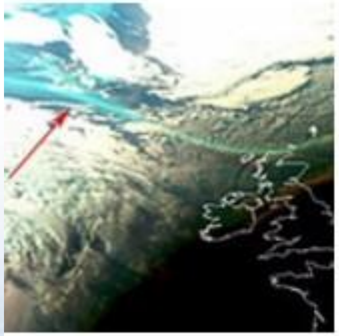


MIDSUMMER FIRES

23 June 2015

Large Midsummer fires in Spain, on the evening of 23 June, were detected by Metop-A's 3.7μm channel.

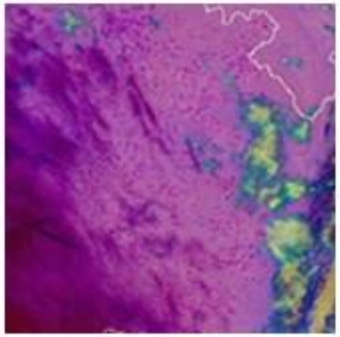
http://www.eumetsat.int/website/home/Images/ImageLibrary/index.html



SMOKE FROM CANADIAN FIRES SEEN OVER EUROPE

13 June 2015

On 13 June smoke from wildfires in Canada travelled over parts of Northern Europe.



TRADITIONAL BELTANE FIRES SEEN BY METOP

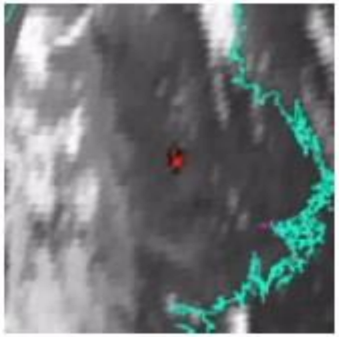
30 April 2015

Hotspots from balefires in parts of Europe could be seen on the Metop image from 30 April.

FIRES OVER THE SOUTH-WESTERN PARTS OF SOUTH AFRICA

12 February 2015

Many runaway/out of control fires over the south-western parts of



LARGE FOREST FIRE IN SWEDEN

04 August 2014

Meteosat and Suomi-NPP imagery of a large forest fire in Sweden showing hot spots with temperatures up to 356 K.

http://www.eumetrain.org/data/3/30/index.htm

Forest Fires

Table

The Fire Triangle
Weather
The Continuity Equation
Fuel
Topography
Fire Weather Index
Summary

Table of Contents
Print Version
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As you have seen in the previous chapter, synoptic patterns are not enough to indicate the locations where forest fires are likely to occur and spread. In fact, aside from the weather, a fire's behaviour also strongly depends on fuel and topography, creating the three sides of what is usually known as the *fire triangle* (Figure 3.1).

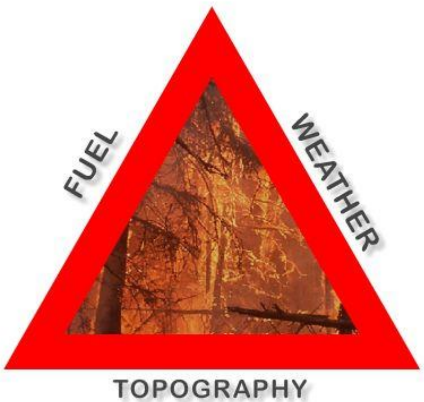

Fig 3.1 – Fire triangle. Fire hazards are influenced by fuel, weather and topography.

In this third chapter the three sides of this triangle will be further explained. After answering the following multiple choice question the chapter will continue with "weather".

Fire ignition depends most on which of the following meteorological factors:

a) Temperature

Contents

Characteristics of SEVIRI channels

- Characteristics of the 3.9µm channel
- Solar channels for monitoring vegetation

Physical concepts

- Sub-pixels effects

Remote sensing of fires and vegetation

- Scars in solar channels
- Land products
- Smoke

Exercise and quiz

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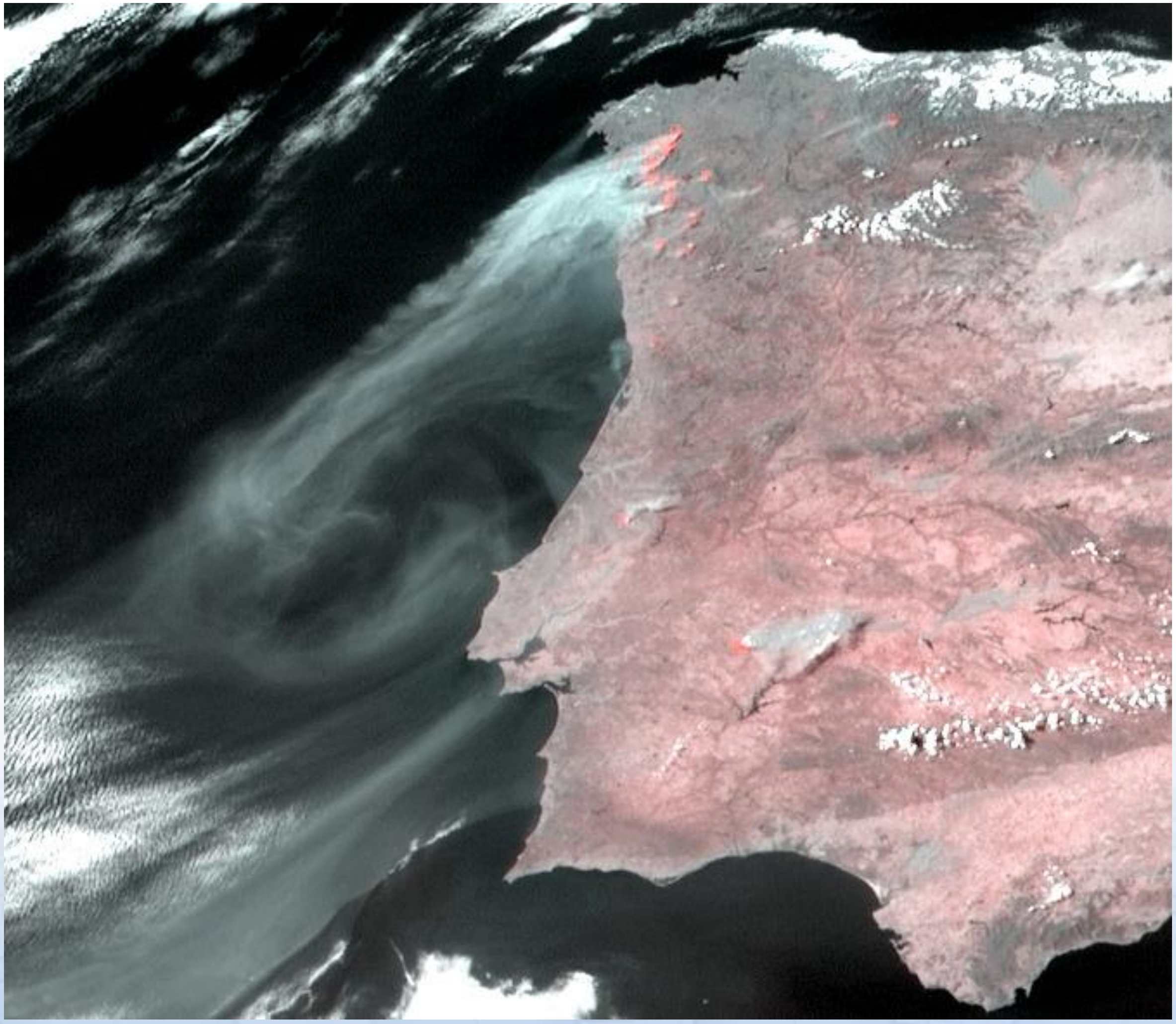

Meteosat: 30% of channel 3.9µm on top of HRV

2006-July-7 16:00

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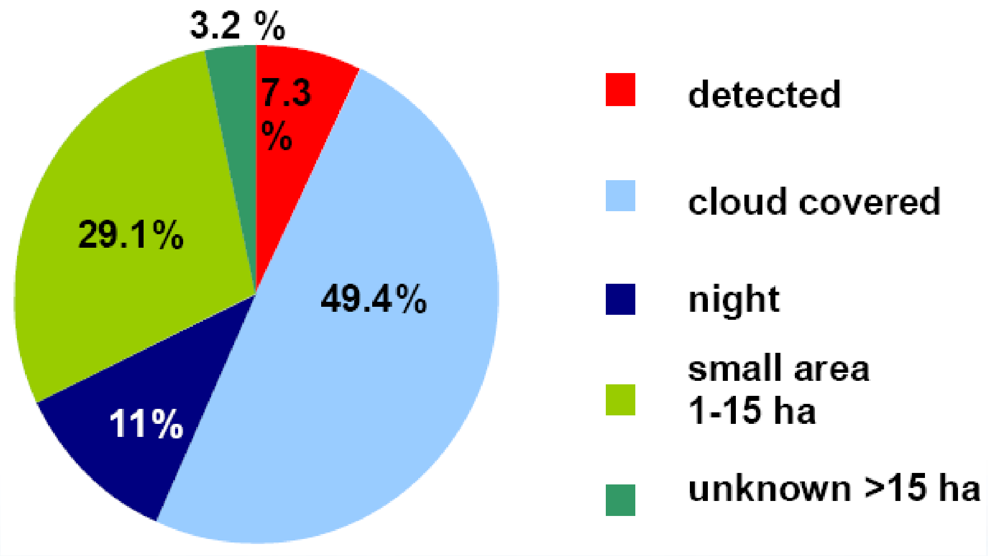
Satellite detection of fires



- Study in Croatia, N Strelec, for 2007-2009
- Average: 750 fires/year, 160.000 Ha , <x> = 1.5 km average horizontal dimension
- Poor performance of satellites due to: small active surface, cloud or smoke cover, location uncertainty (for fire brigades)

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SEVIRI CHANNELS

Channel	Properties: Cloud	Properties: Gases	Application	
HRV 0.7	Absorption <----------> Scattering; 1 <------ Emissivity ------> 0	Broad band VIS	Surface, aerosol, cloud detail (1 km)	12
VIS 0.6		Narrow band	Ice or snow	1
VIS 0.8		Narrow band	Vegetation	2
NIR 1.6		Window	Aerosols, **snow<>cloud**	3
IR 3.8		Triple window	SST, **fog**<>surface, ice cloud	4
WV 6.2		Water vapour	**Upper** troposphere 300 Hpa humidity	5
WV 7.3		Water vapour	**Mid**-troposphere 600 Hpa humidity	6
IR 8.7		Almost window	Water vapour in boundary layer, **ice<>liquid**	7
IR 9.7		Ozone	Stratospheric winds	8
IR 10.8		Split window	CTH, cloud analysis, **PW**	9
IR 12.0		Split window	Land and **SST**	10
IR 13.4		Carbon dioxide	+10.8: Semitransparent-cloud **top**, air mass analysis	11

Why 3.9µm for fire?

Please type short suggestions here

3.9µm characteristics: mark the true!

Maximum emission by flames

Response to subpixel thermal anomalies

Small sun contribution

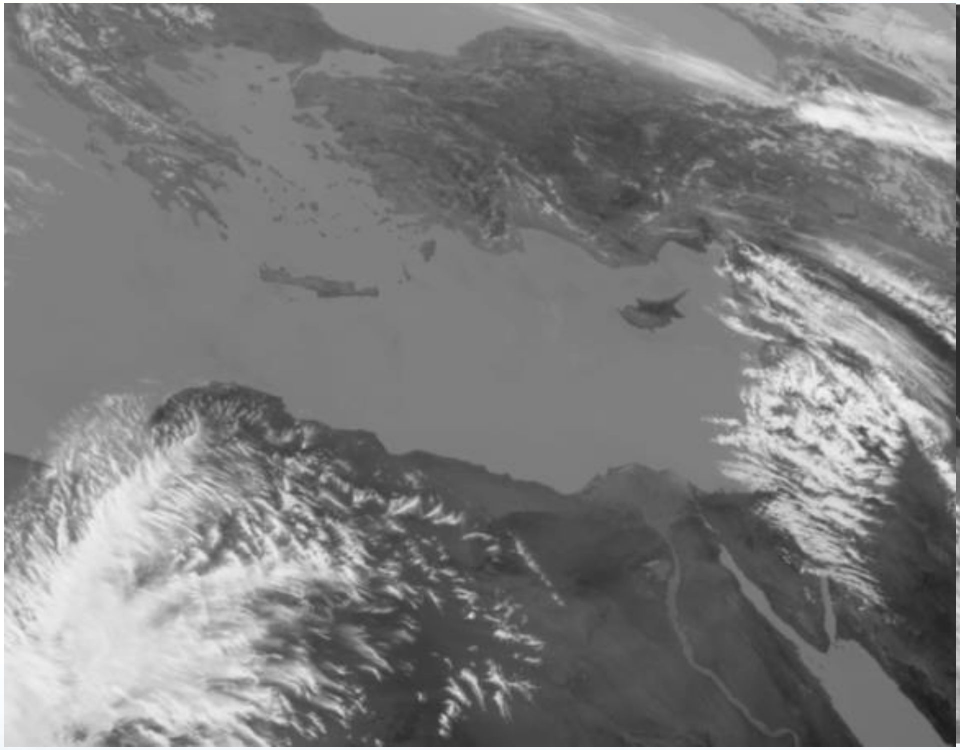
No absorption by water vapour

No absorption by carbon dioxide

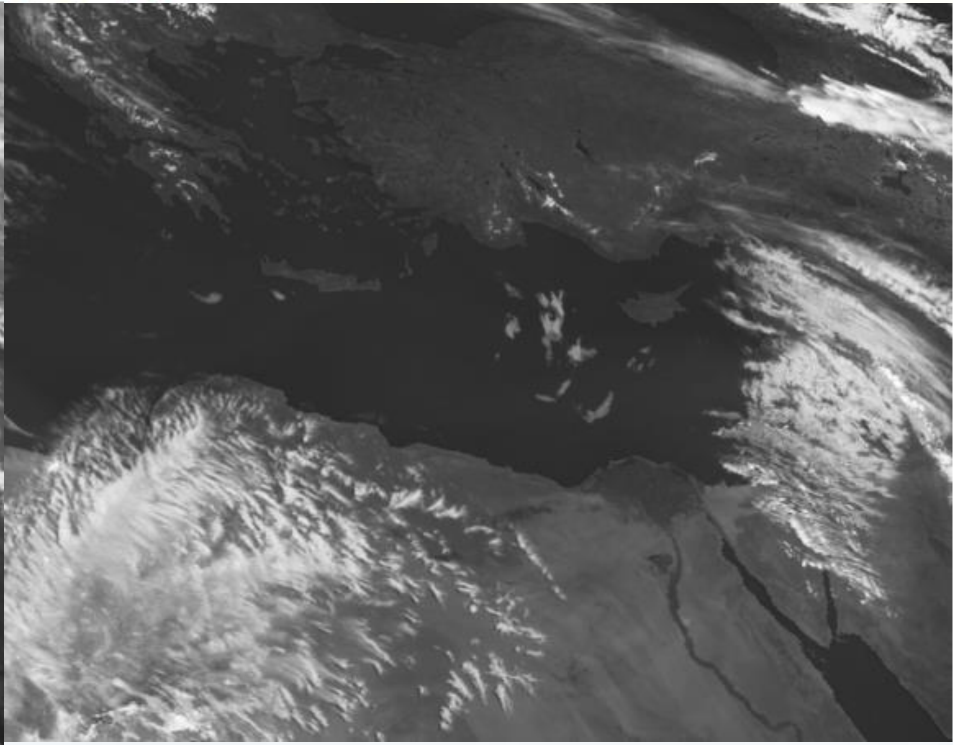
Meteosat pixel saturation for fires

Low ground emissivity

3.9 µm and 10.8µm channels: IR window channels



2016_Apr_05 10UTC Channel 10.8µm [215K .. 315 K]



Difference 3.9µm - 10.8µm [-8K .. +60K]

Differences 3.9µm – 10.8µm due to:

Sun (+20K), gas absorption (-5K), ground type(+-3K) and ... Planck (+5K)

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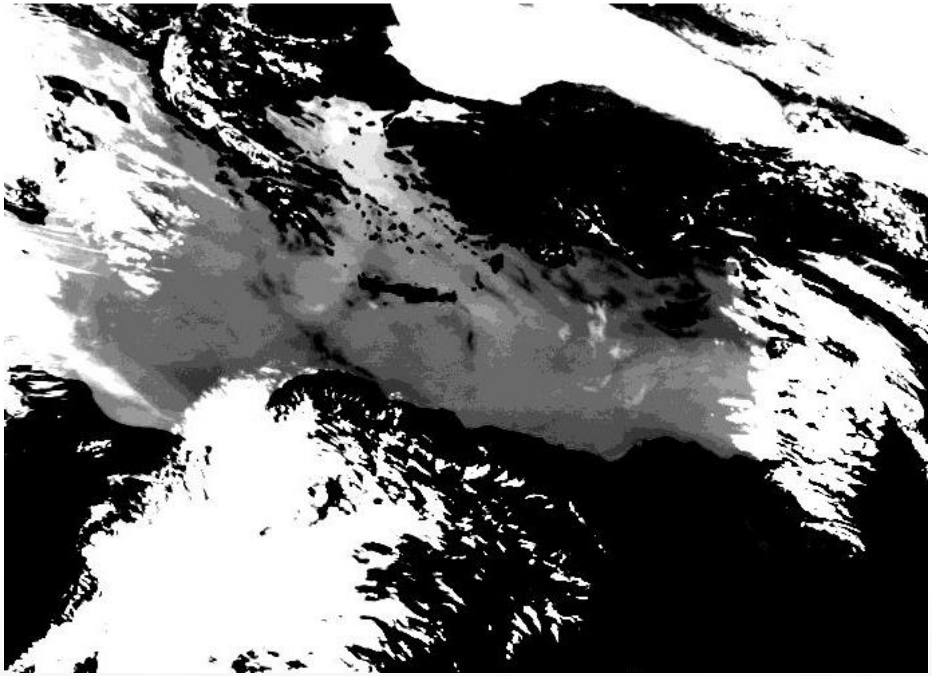
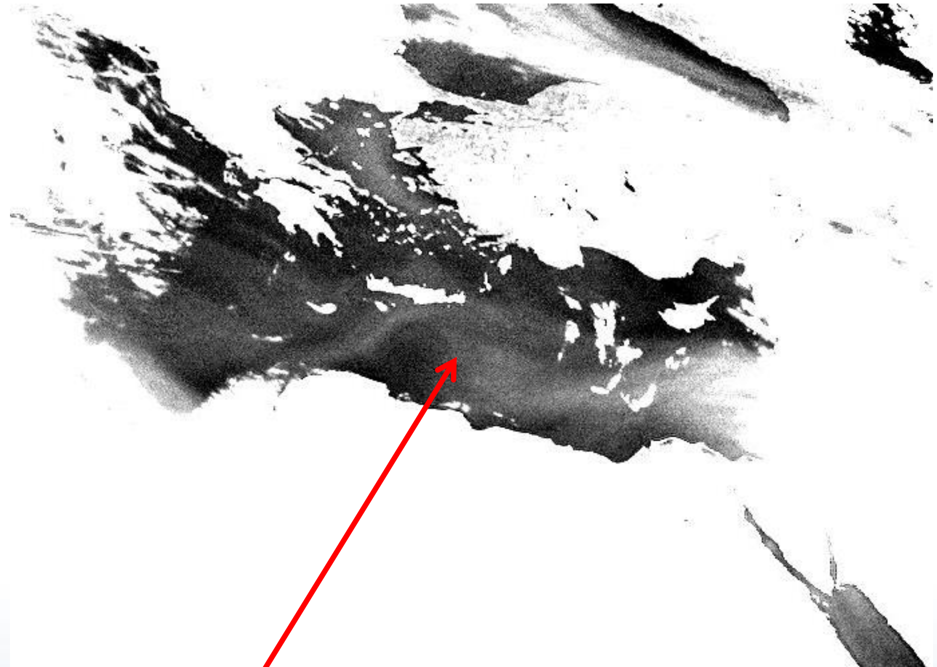


2016_Apr_05 10UTC Channel 10.8µm [215K .. 315 K]



Difference 3.9µm - 10.8µm [-8K .. +60K]

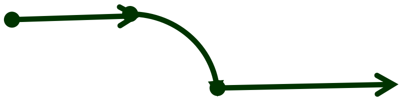
Over water, 10.8µm roughly shows SST fields

But 3.9µm – 10.8µm shows humidity at low level

3.9 µm and 10.8µm: window channels

3.9 µm

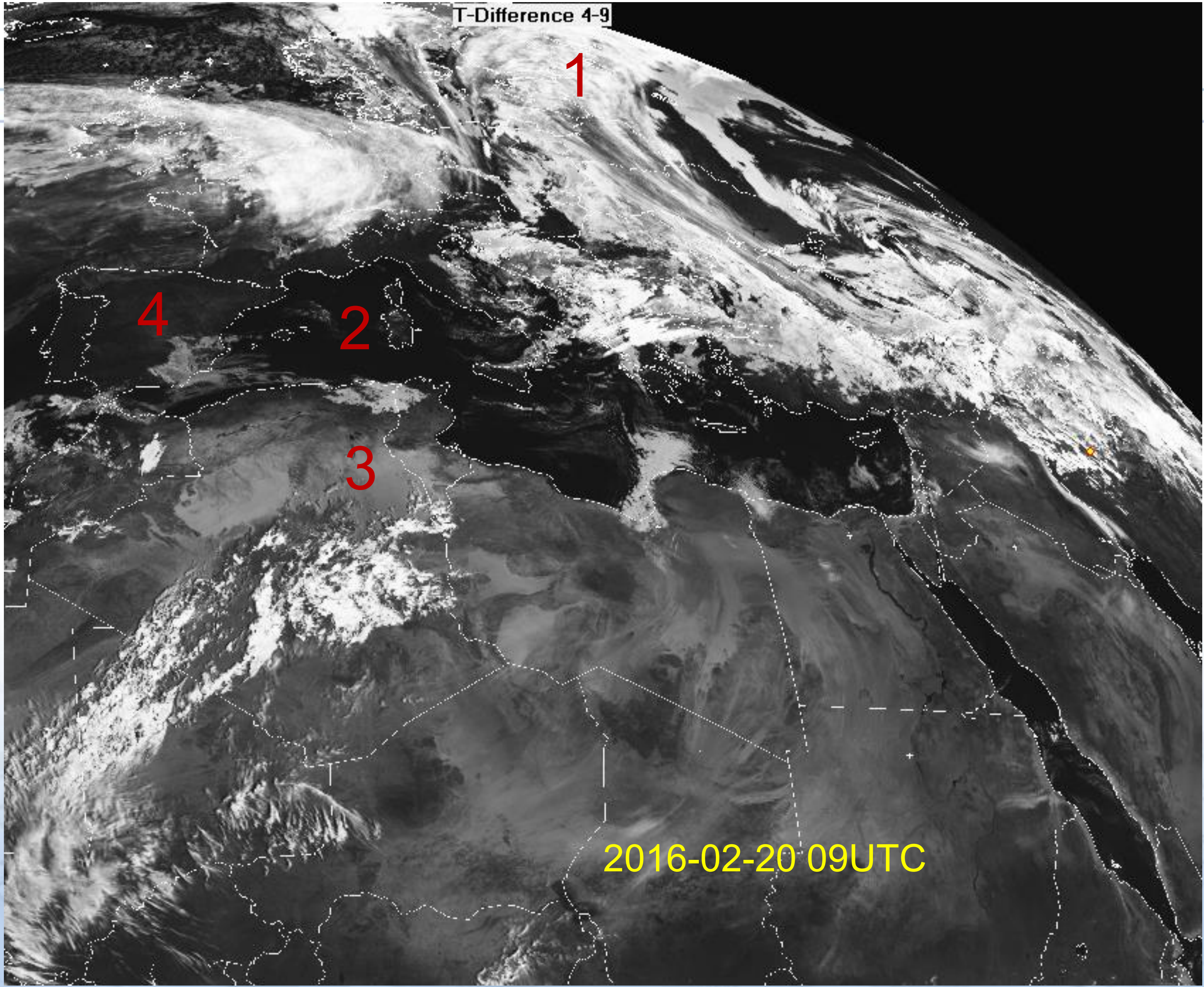
- ❖Negligible absorption by atmospheric humidity
- ❖Close to a **CO_2 absorption** band, 4-7 Kelvin signal reduction
- ❖High temperature **sensitivity** (big sub-pixel effects) ~14 * $\Delta T/T$
- ❖**Blinding** effect by hot pixels, affecting measurements west of the saturated pixel
- ❖Fog warnings: daytime start or night dissipation onset

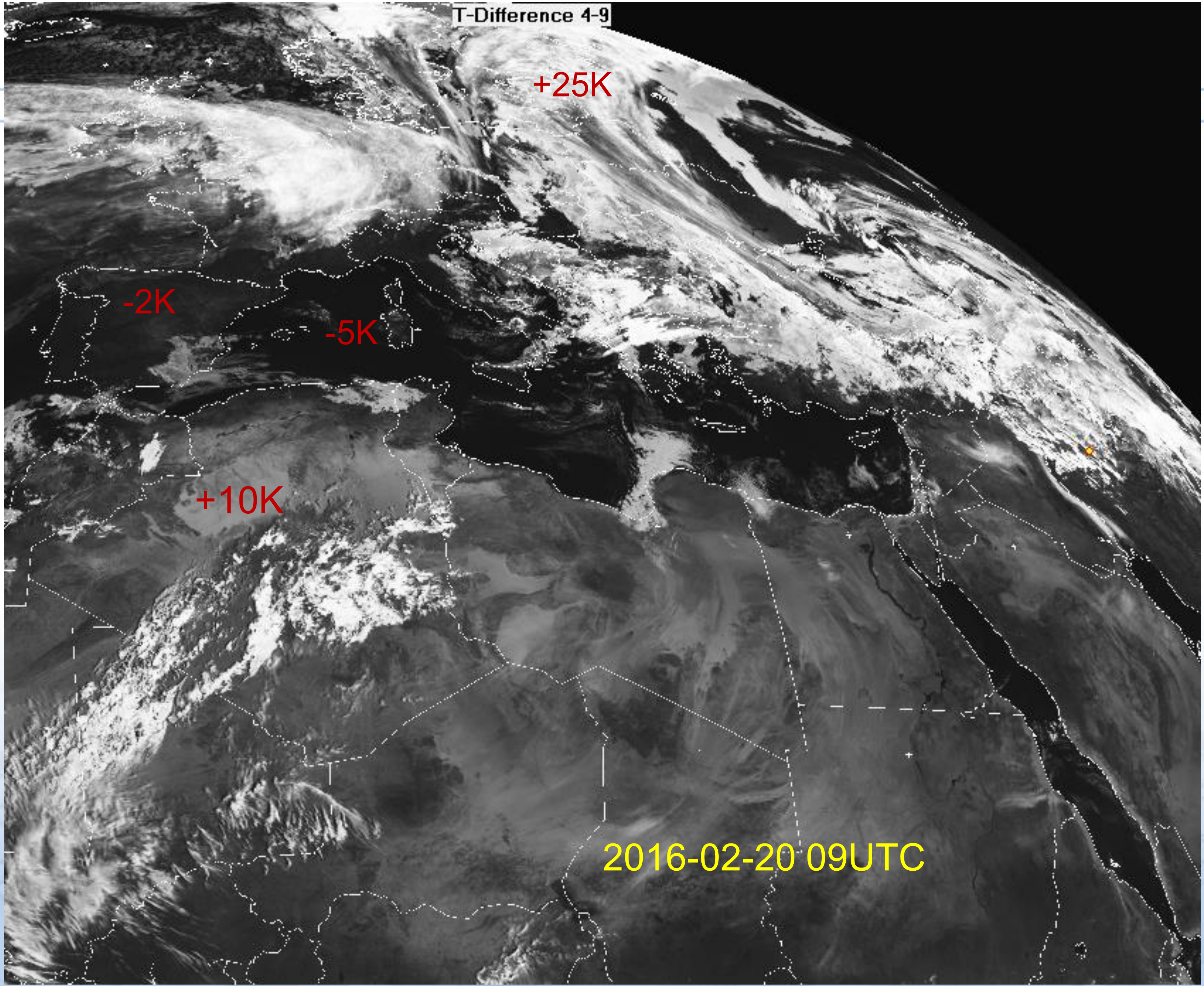


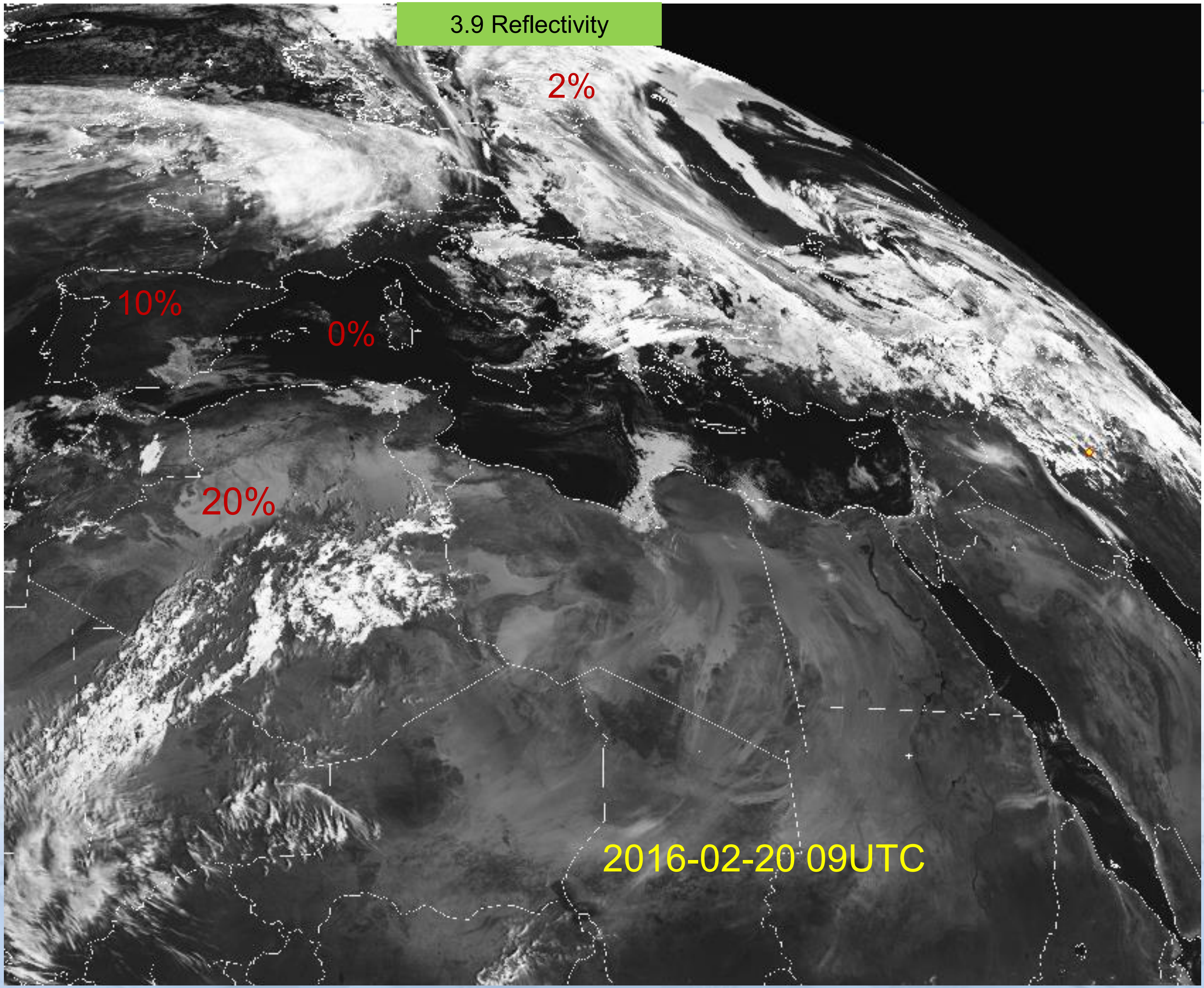
- ❖**Sun** enhancement during day, emission effects during night

10.8 µm

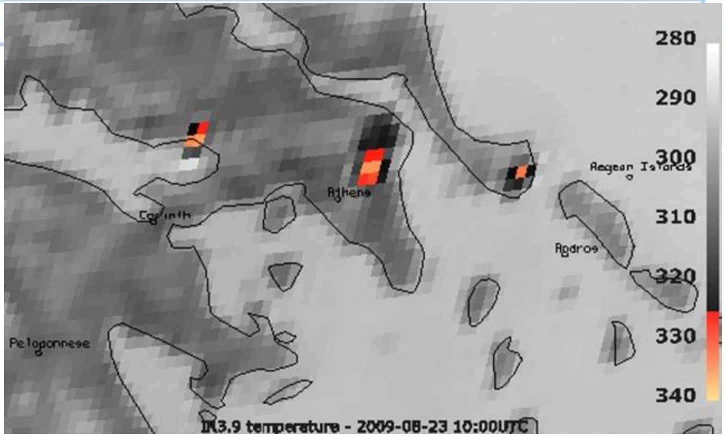
- ❖1-2 Kelvin absorption by atmospheric humidity
- ❖No signal reduction by CO_2
- ❖Lower temperature sensitivity (small subpixel effects) ~ 4 * $\Delta T/T$
- ❖No risk of sensor blinding by fires
- ❖Low values compared with 3.9µm due to semitransparent cloud or smoke.

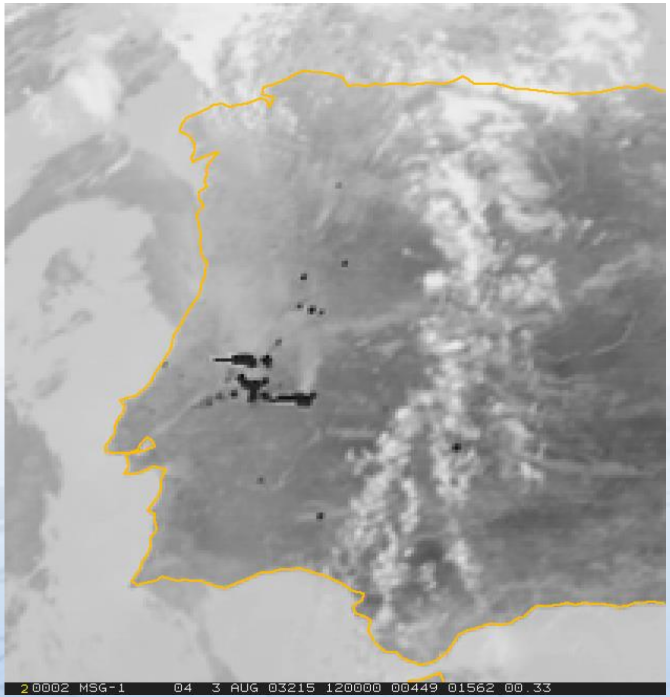

T-Difference 4-9
1
2
3
4
2016-02-20 09UTC
-5K
-2K
+10K
+25K


T-Difference 4-9
+25K
-2K
-5K
+10K
2016-02-20 09UTC

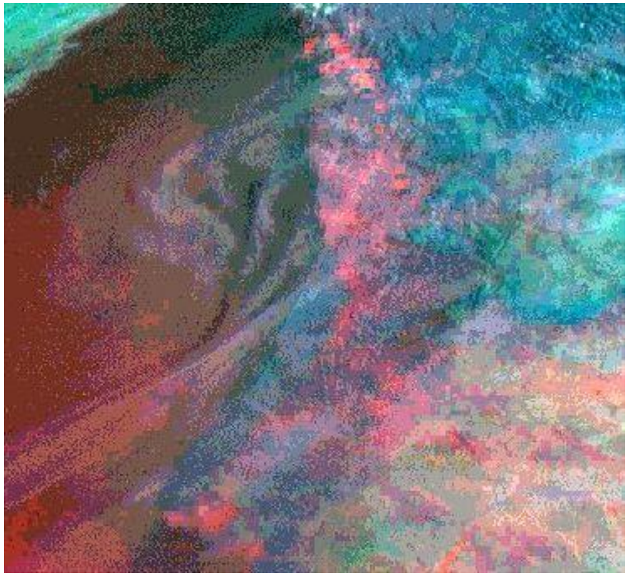

3.9 Reflectivity
2%
10%
0%
20%
2016-02-20 09UTC

3.9 µm and 10.8µm channels: sensor blinding and filters





For pixels west of the fire the sensors can be blinded, following geometrical patterns (**rings**)



2006_08_07 06-19UTC
rgb_12 + 4-3-2
HRV can be combined with lower horizontal resolution for more spectral information

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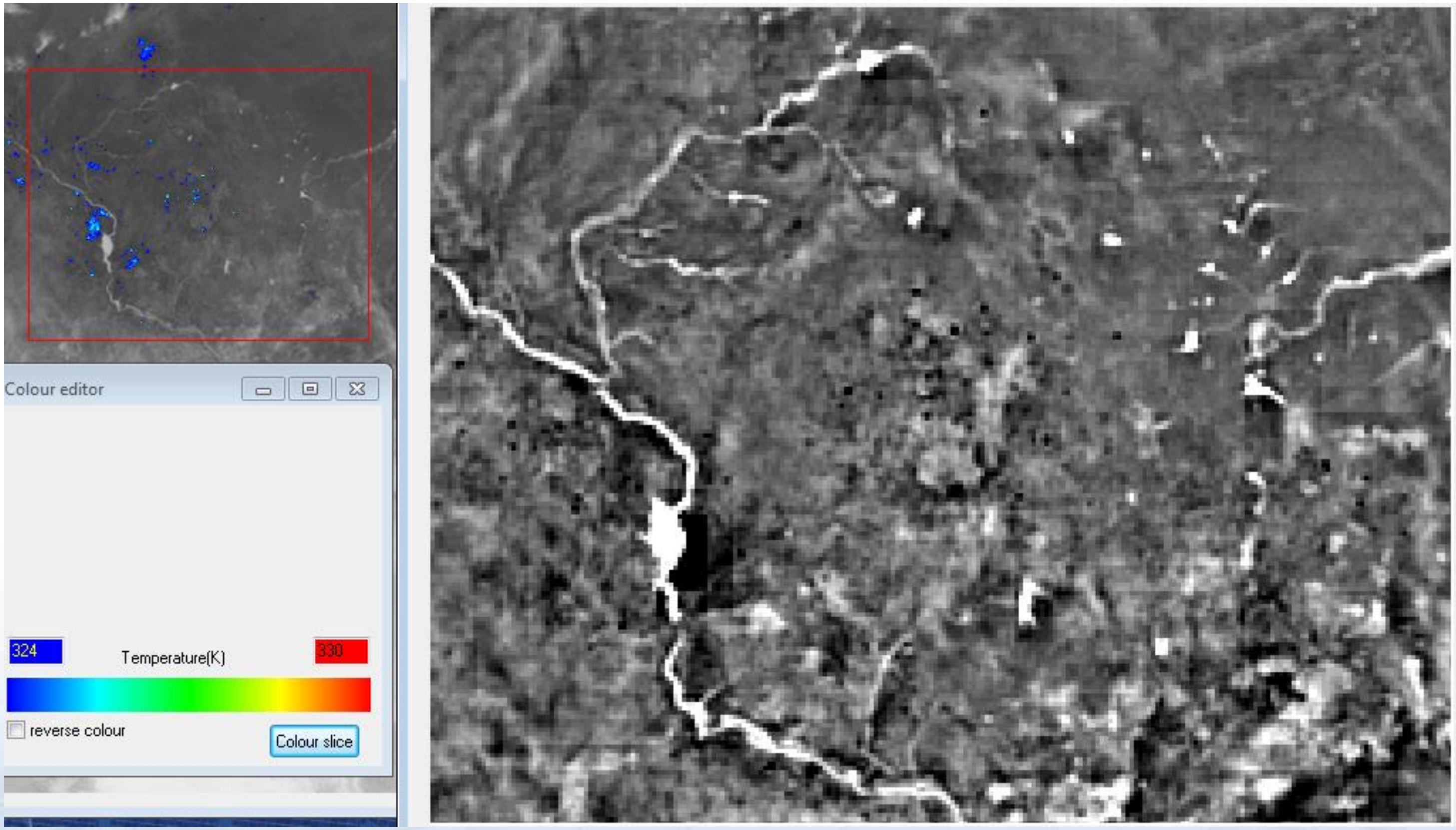
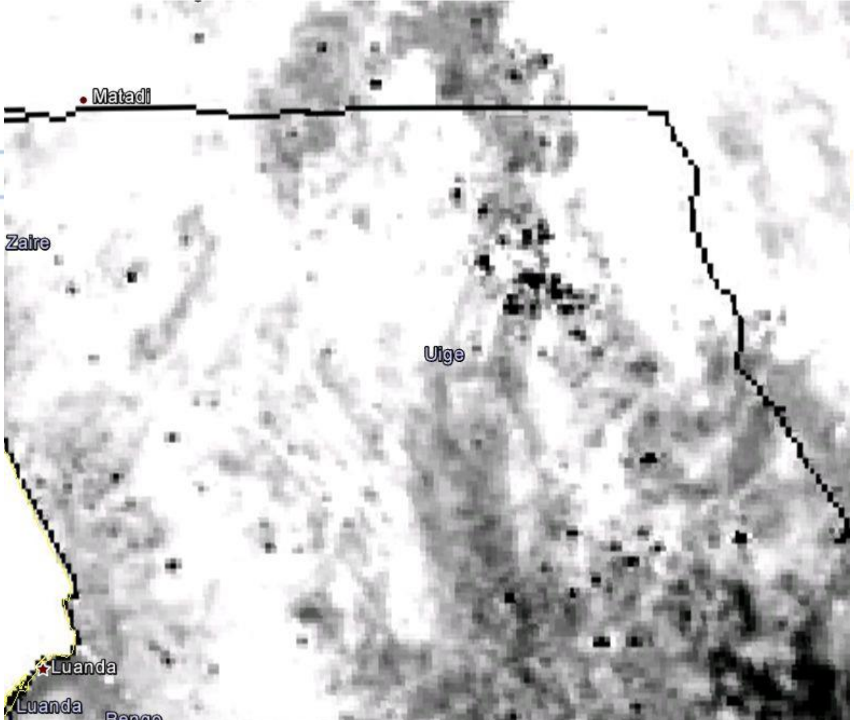


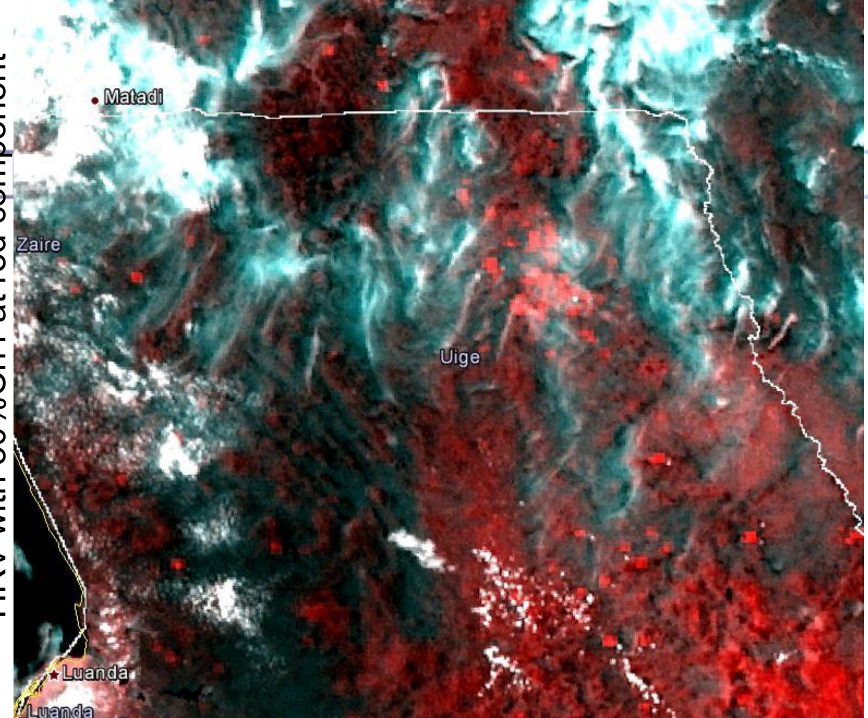
2015-02-09_15UTC, channel 4, Meteosat-10

Contrast with neighbours is better than thresholds in 3.9 µm to spot **fires**

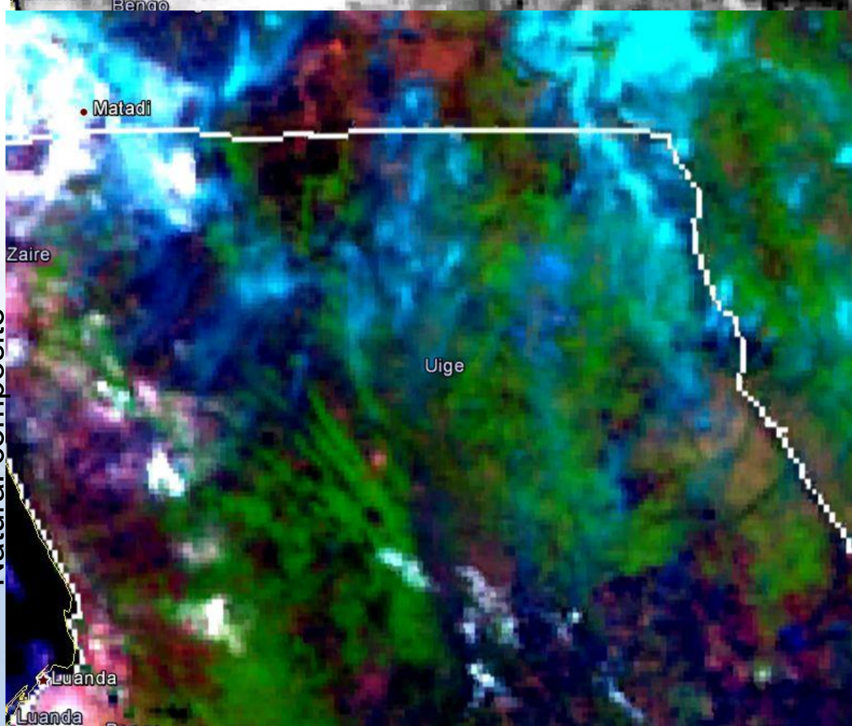
Channel 4 2011-09-01 12:00 M9



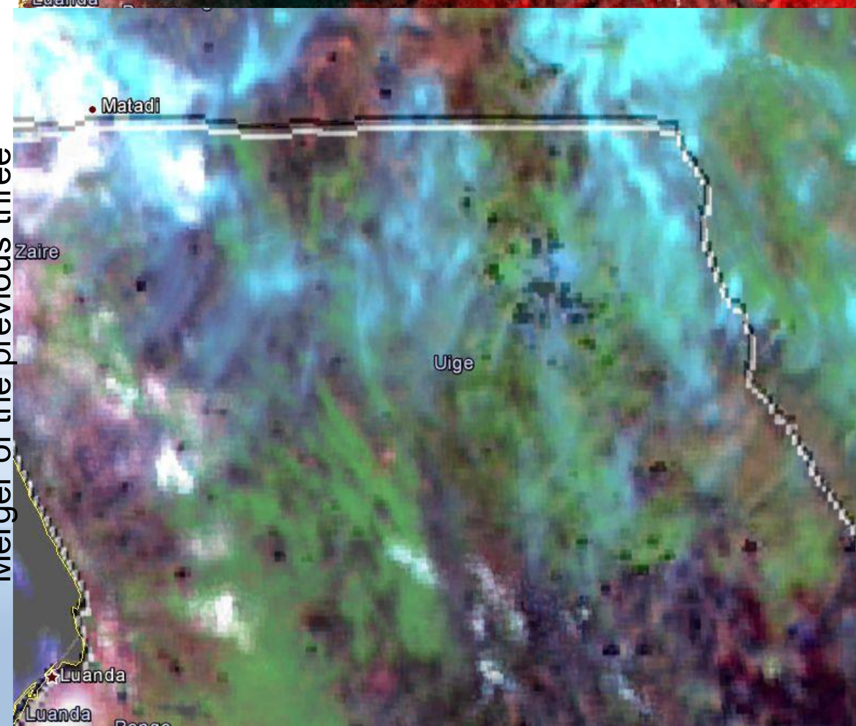
HRV with 30%Ch4 at red component



Natural composite

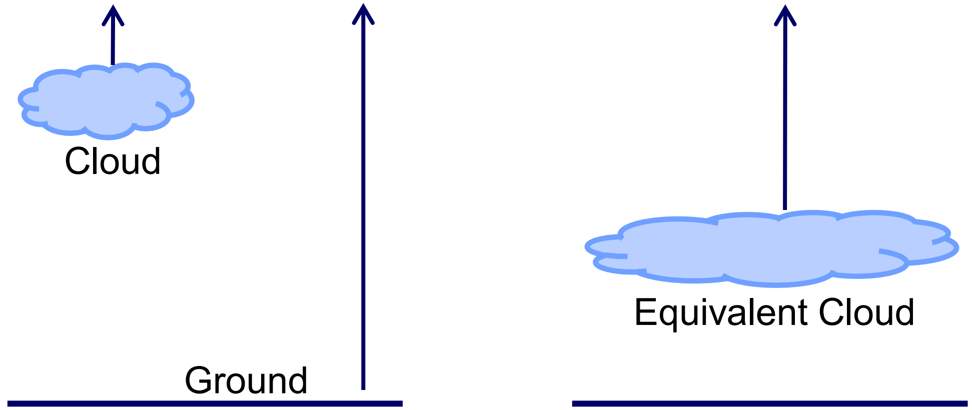


Merger of the previous three

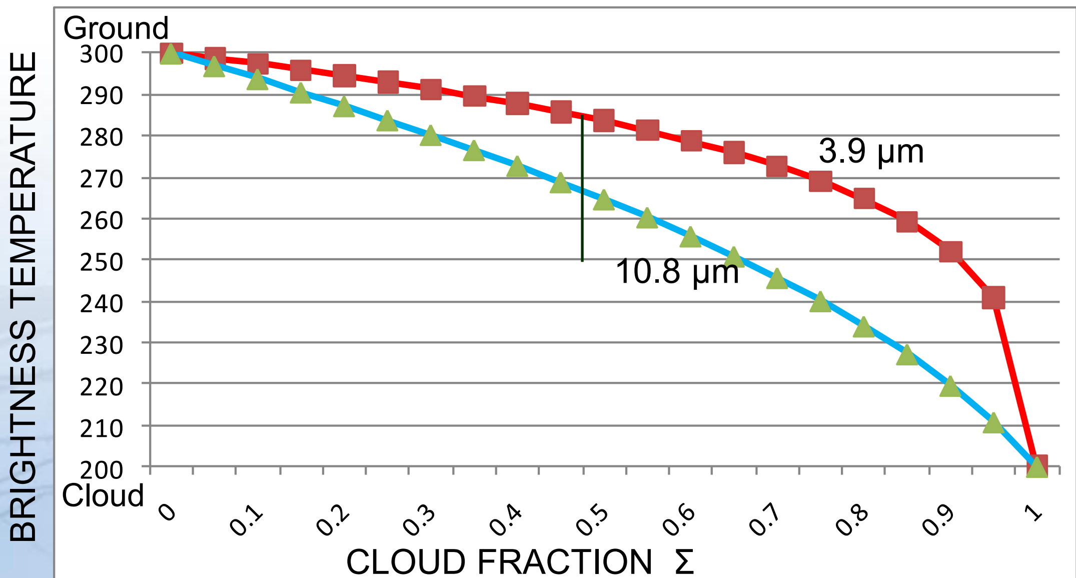


Sub-pixel effects = temperature sensitivity = warm bias

$$\Sigma \cdot B_C + (1-\Sigma) \cdot B_G = B_{EC}$$



The equivalent temperature is not the average temperature, but shows a WARM BIAS!



50% cloud gives:

282 K (at 3.9 µm)

264 K (at 10.8 µm)

and NOT the average 250 K

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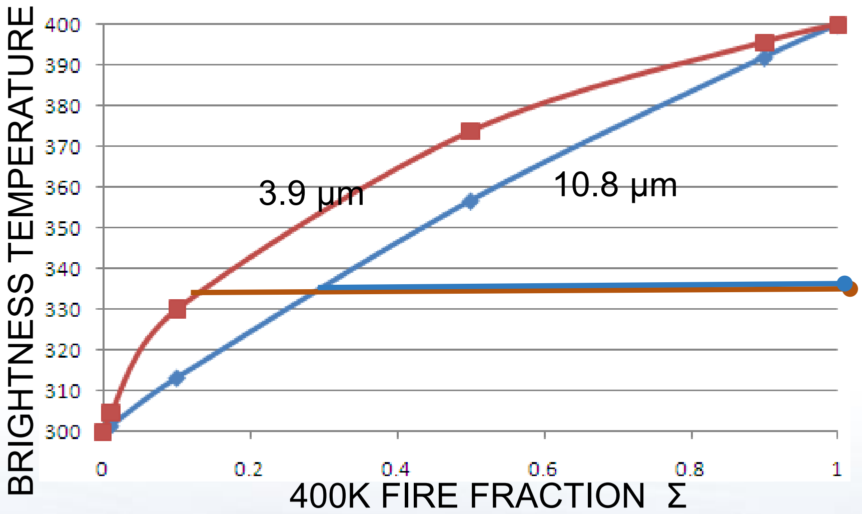
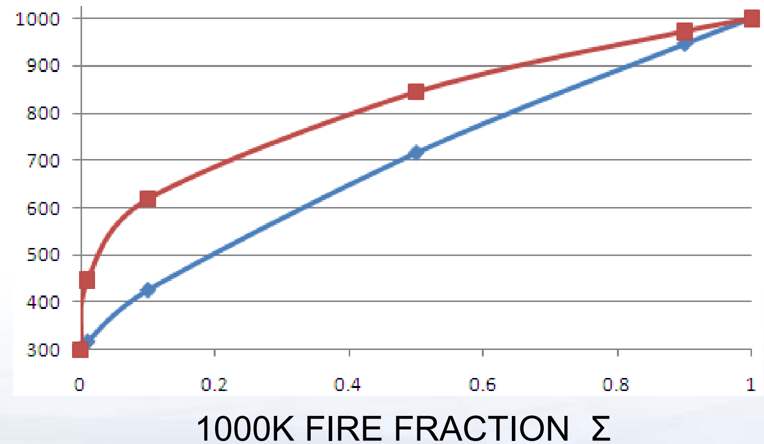
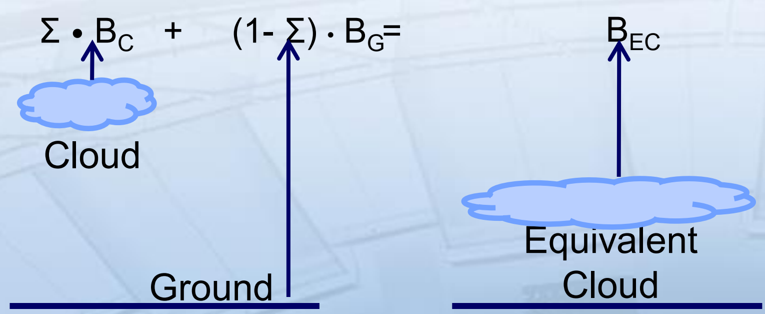
Subpixel effects = temperature sensitivity = warm bias

Widespread fires (15%) show less difference 3.9µm – 10.8µm than small ones (5% of the pixel)







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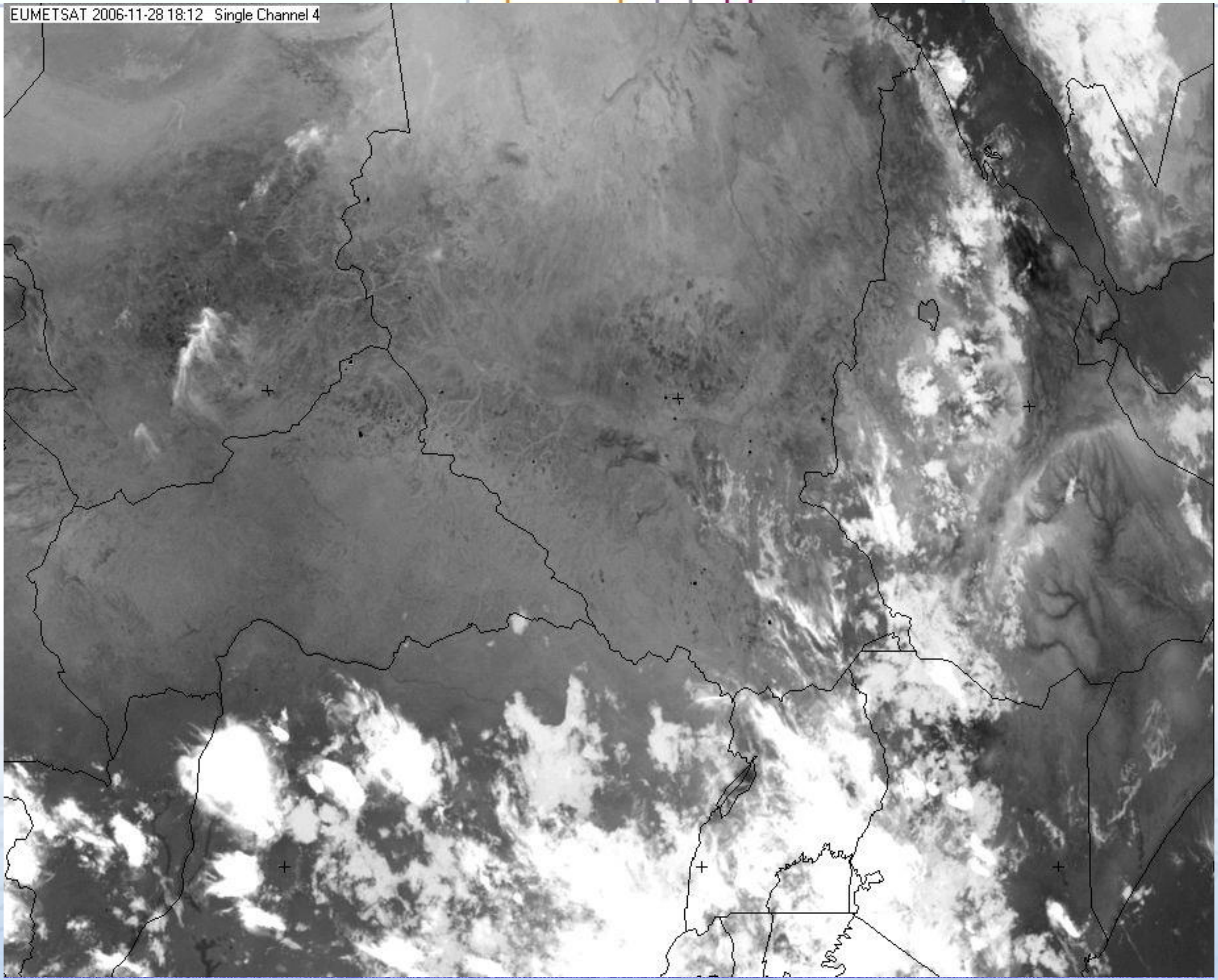
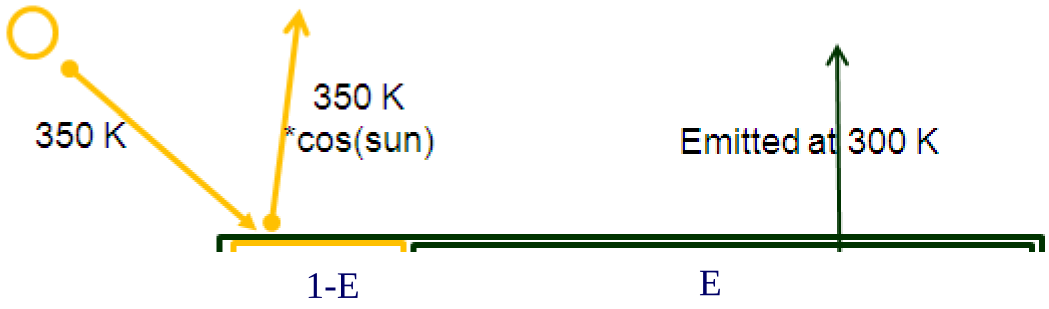
Fires on 1.6µm images



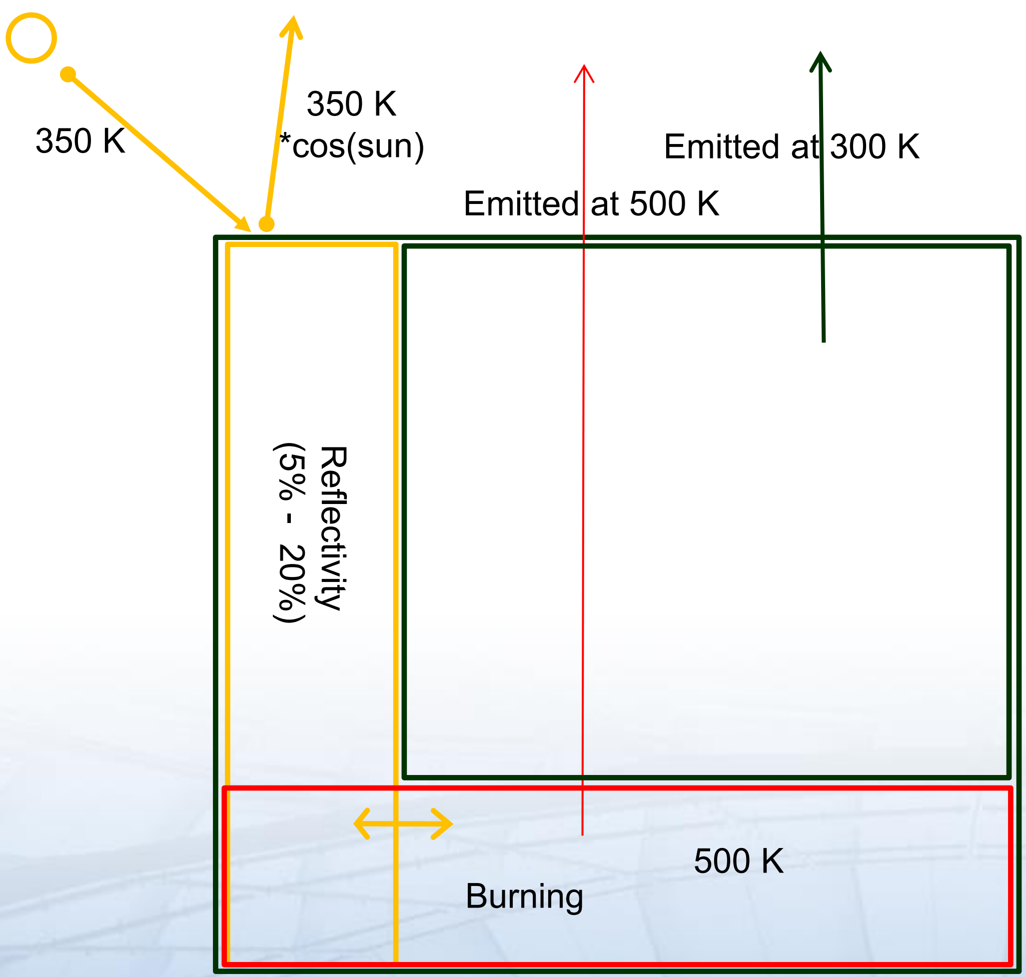
Solar reflection and emission together (3.9µm)



$$B(BT) = (1-E) * B(350K) + E * B(300K)$$

- Warm bias in brightness temperature towards 350K (depends on illumination)
- During night, brightness temperature (BT) is lower than 300K
- Albedo (1-E) varies with type of soil: 20% (savannah) to 5% (forest)
- Cloud (1-E=2%) is usually present in burning areas

Hot spots contributions in a pixel (3.9µm)



DAY BT Fraction burning	Reflectivity 3.9µm 5% Forest	 20% Savannah
0	314	333
0.01	328	339
0.1	380	370
0.5	449	425
1	490	460

NIGHT BT Fraction burning	Reflectivity 3.9µm 5%	 20%
0	296	284
0.01	318	304
0.1	377	356
0.5	448	421
1	489	457

Sunrise and sunset change 3.9µm BT but normally **outside of the detection** range of SEVIRI

Not only 3.9µm allows fire detection

NEAR INFRARED (e.g. 1.6µm)

•More adequate for smoke detection than 3.9µm
•Small fires not visible (below threshold)
•No CO_2 absorption (higher "fire temperature")
•High sub-pixel sensitivity

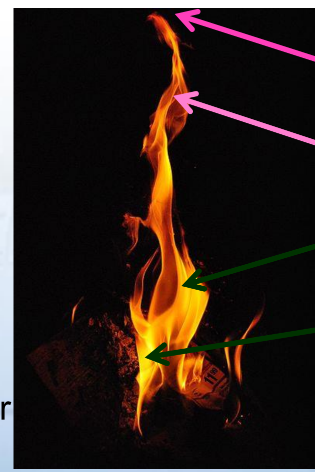
3.9µm

•Hotspots are easily detected
•Total absorption of ground radiation by CO_2
• BT is temperature of the **CO_2 layer** above the fire
•100m minimum fire size for Meteosat pixel
•Sun interference noticeable (~20 K), but truncated by 3.9µm channel dynamic range limit (333K)
•Difficult statistics due to man-made fire generation (e.g. after harvest)

Karthala, Met-8, 29 May 2006, 12:15 UTC
Natural colours RGB 1.6µm-0.8µm-0.6µm

How hot is lava?

Abundant CO_2
..and soot...



500K, air nearby
800K, orange gas
1100K, yellow
1400K, white tones
300K, neighbour pixels

Which one is the "fire temperature"?

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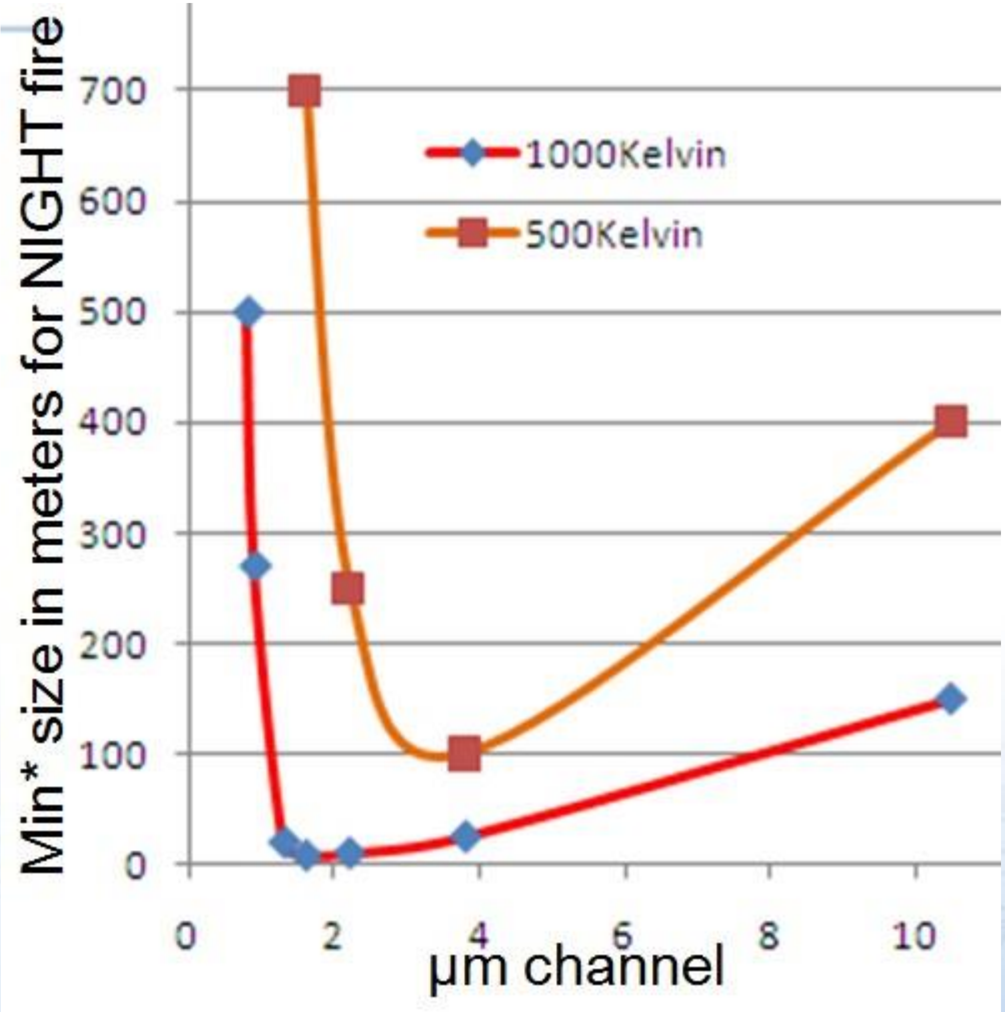
The fire traffic lights

- A fire at 500K will be sensed, as it grows
- first by 3.9µm(at ~100m)
- second by 2.2µm (250m)
- third by 10.8µm (400m)
- An RGB=(3.9;2.2;10.8) might be a good indicator for severity of a fire.
- For a hotter fire (1000K), typically gas flares, channels in the solar domain react faster than 3.9µm



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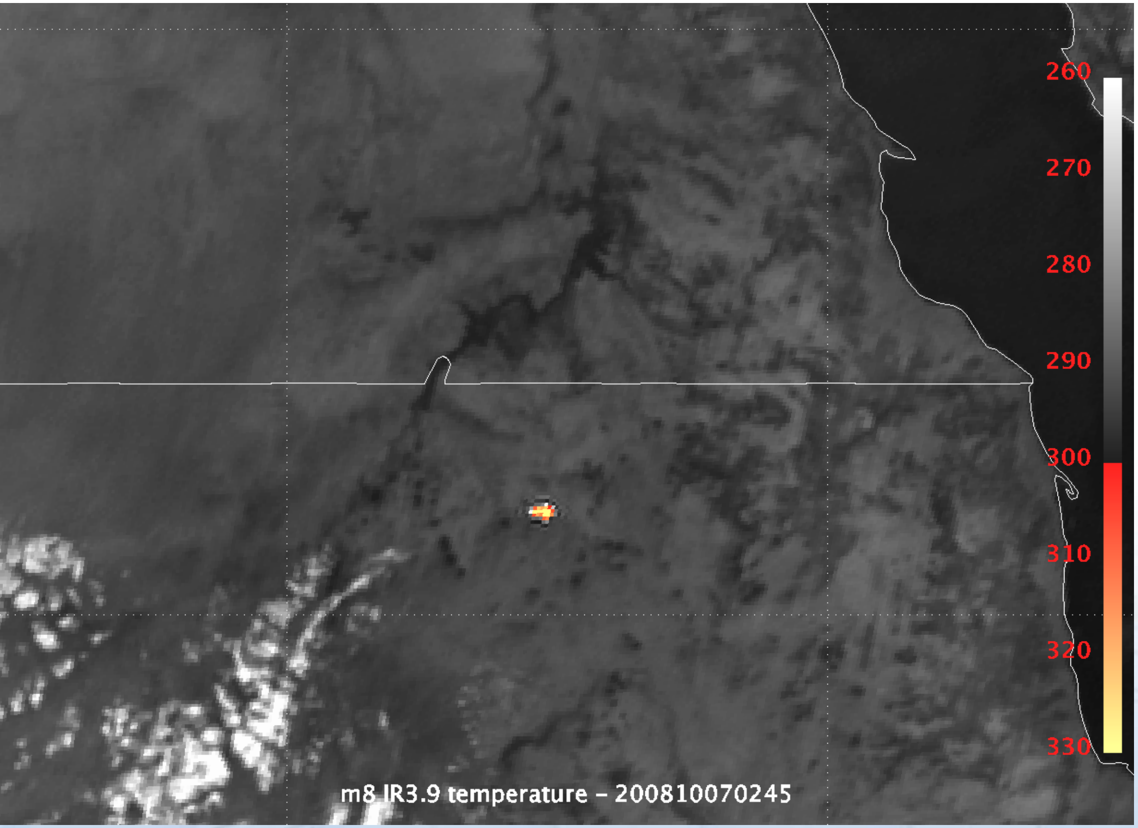
Meteorites on 3.9 µm images



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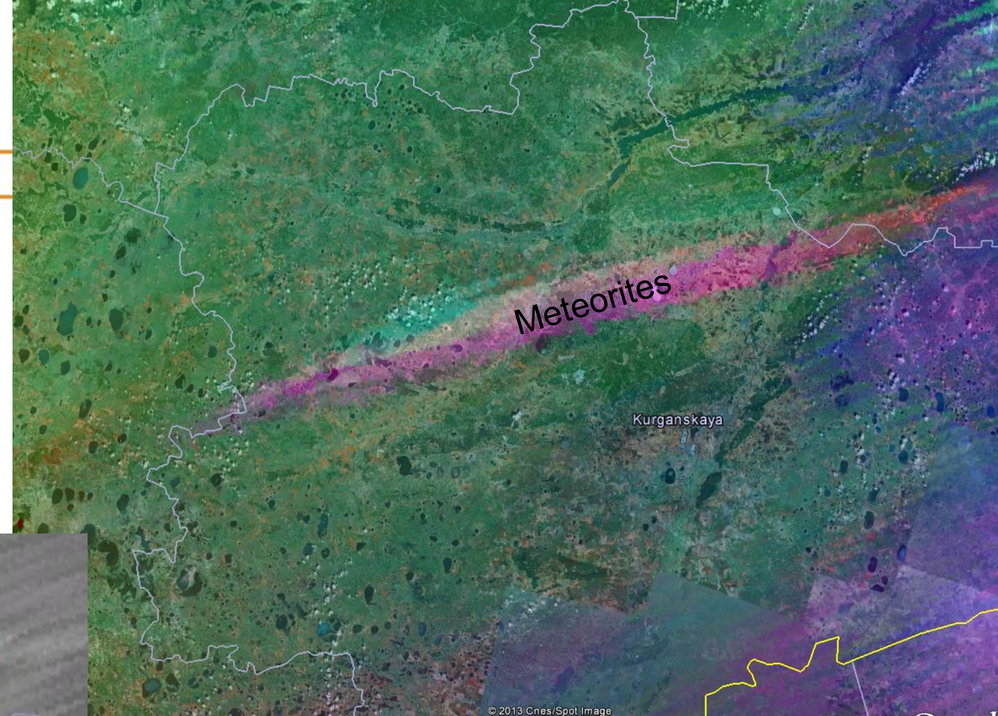
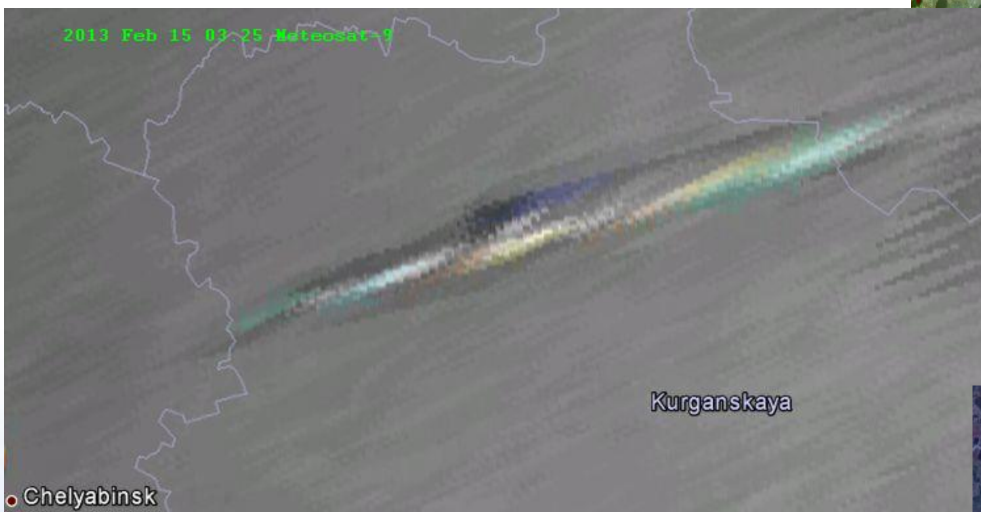
Subpixel detection at 3.9µm

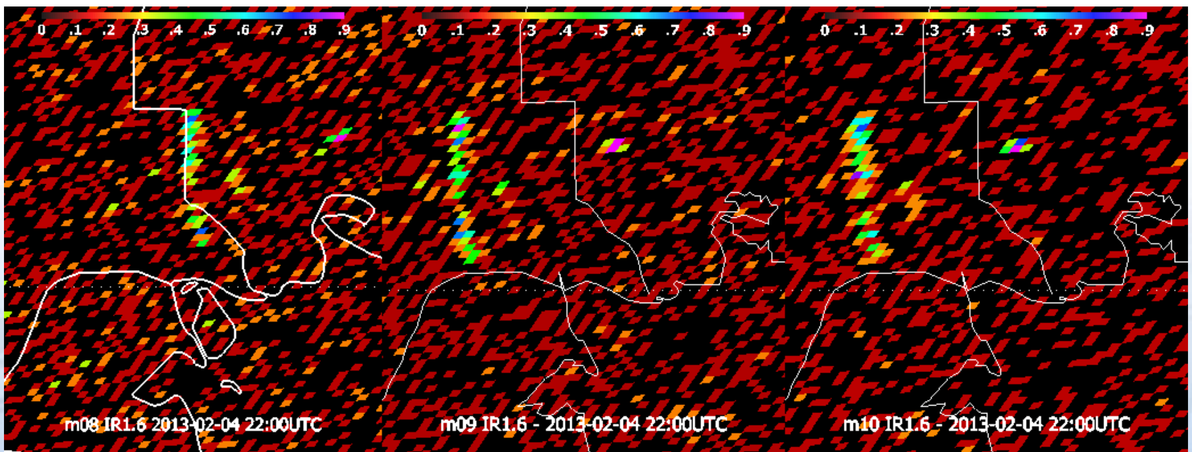




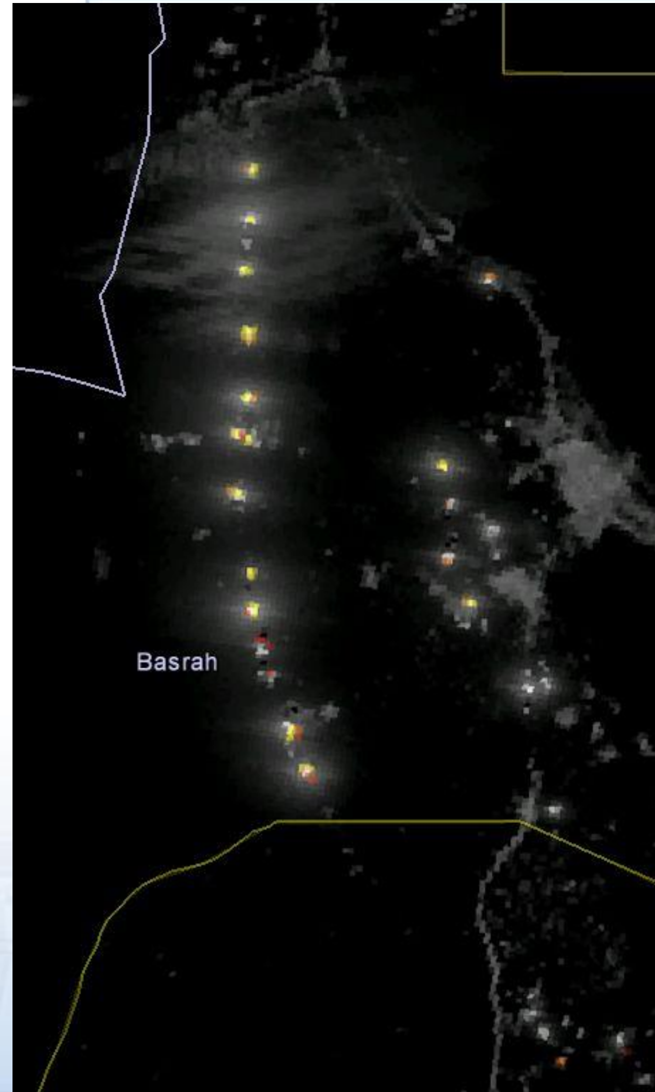
Colour from Meteosat-9 channel 3.9µm.
Blue=270K Red=280K

Meteosat IR dynamic range top limits (kelvin)

Channel (µm)	3.8	8.7	9.7	10.5	12.3	13.3
Absorber	CO_2	Sx	O_3	small	H_2O	CO_2
Dynamic MSG	335	300	310	335	335	300
Dynamic MTG	580	330	310	340	340	300



Meteosat-8,9,10 looking concurrently at gas flares in Kuwait through channel 1.6µm



VIIRS 2013-02-17:2200

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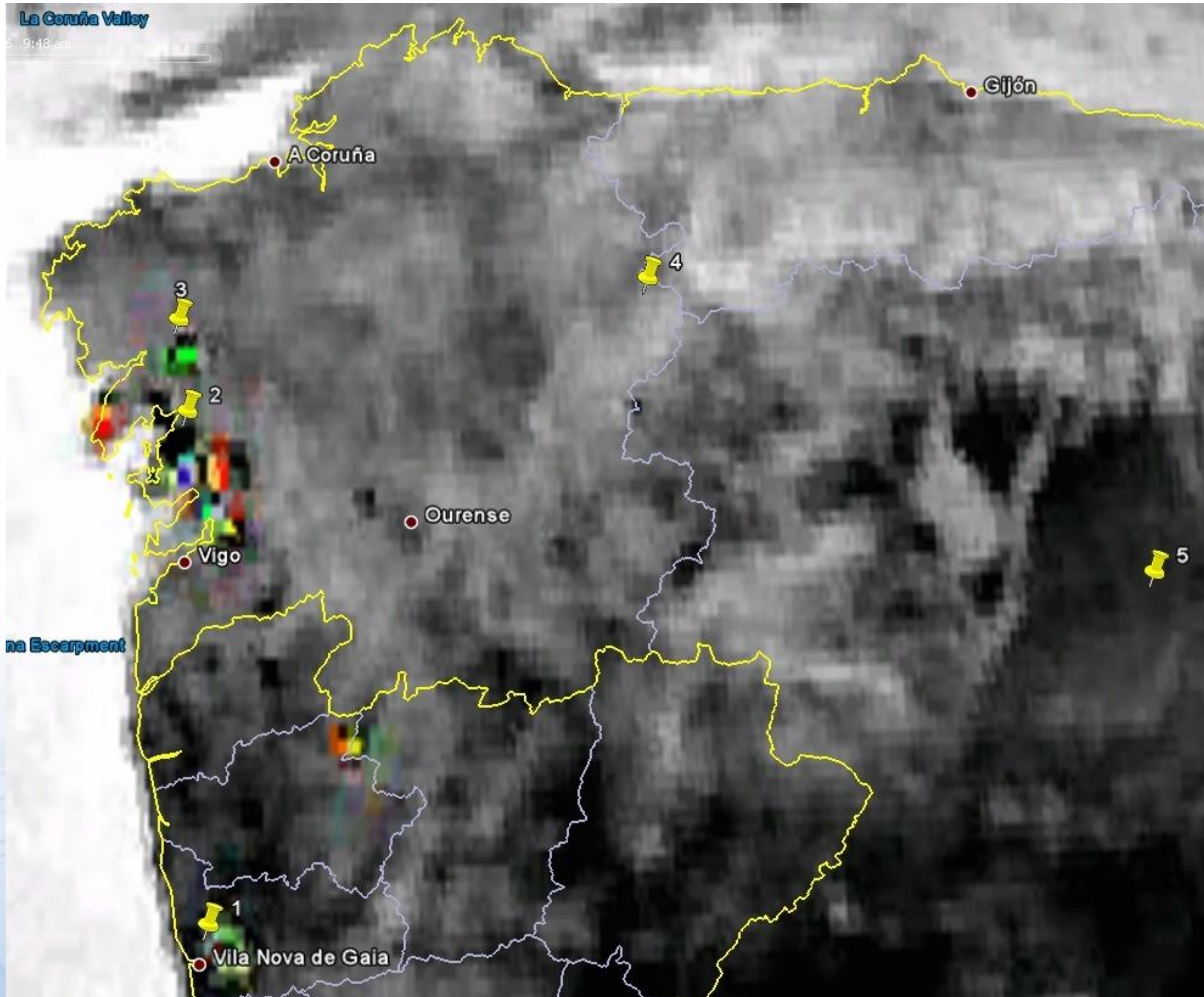
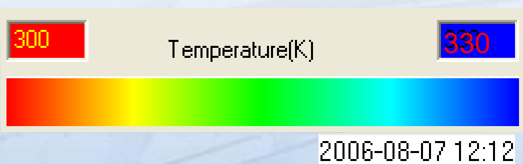
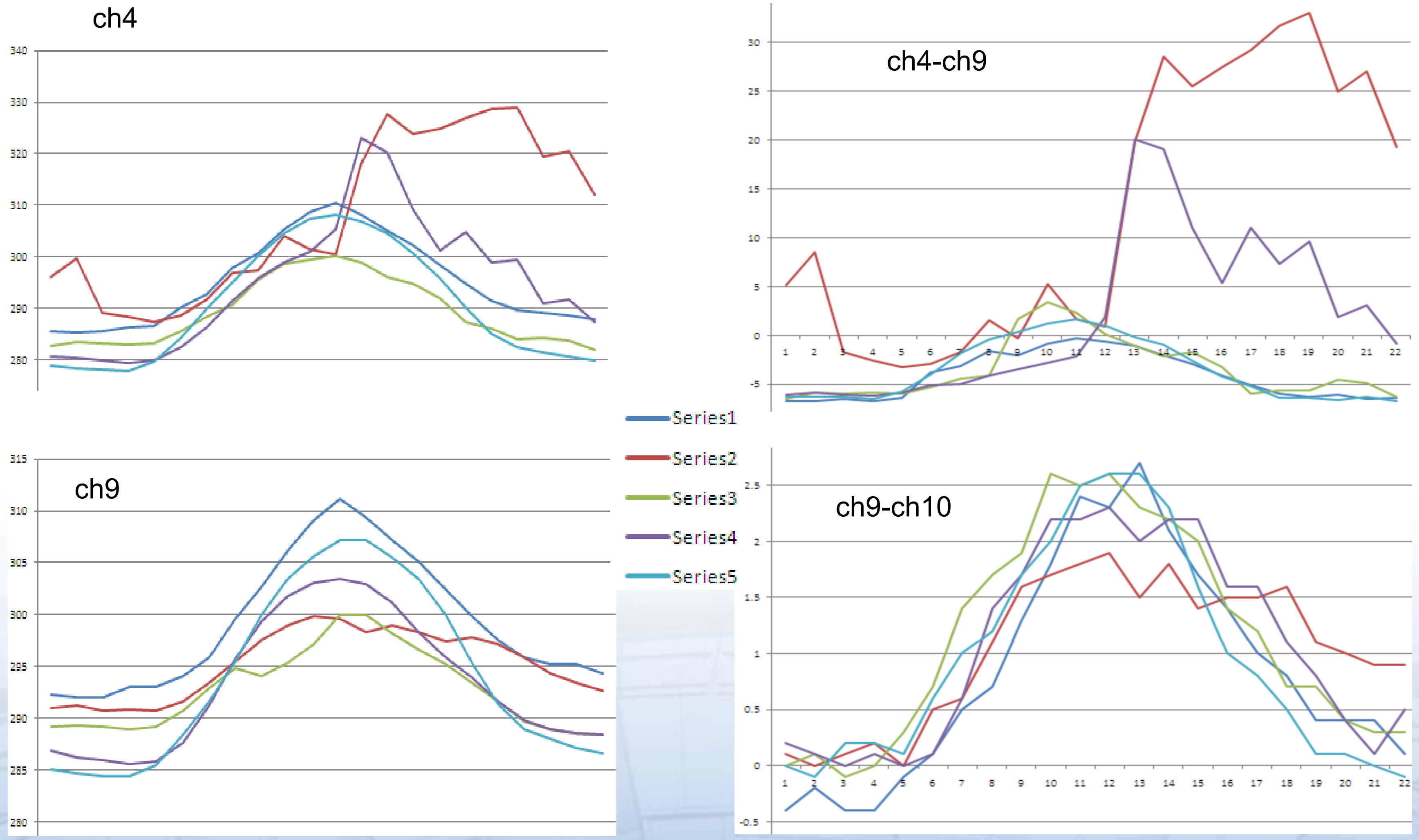
Fires in Galicia (Spain)



Channel at 3.9 µm,
colour enhanced



Hot spots, brightness temperature daily evolution



- Stronger response in 3.9µm than in 10.8µm or 12µm
- Optimal index is 3.9µm – 10.8µm
- Alternative index 10.8µm – 12µm, due to humidity increase?

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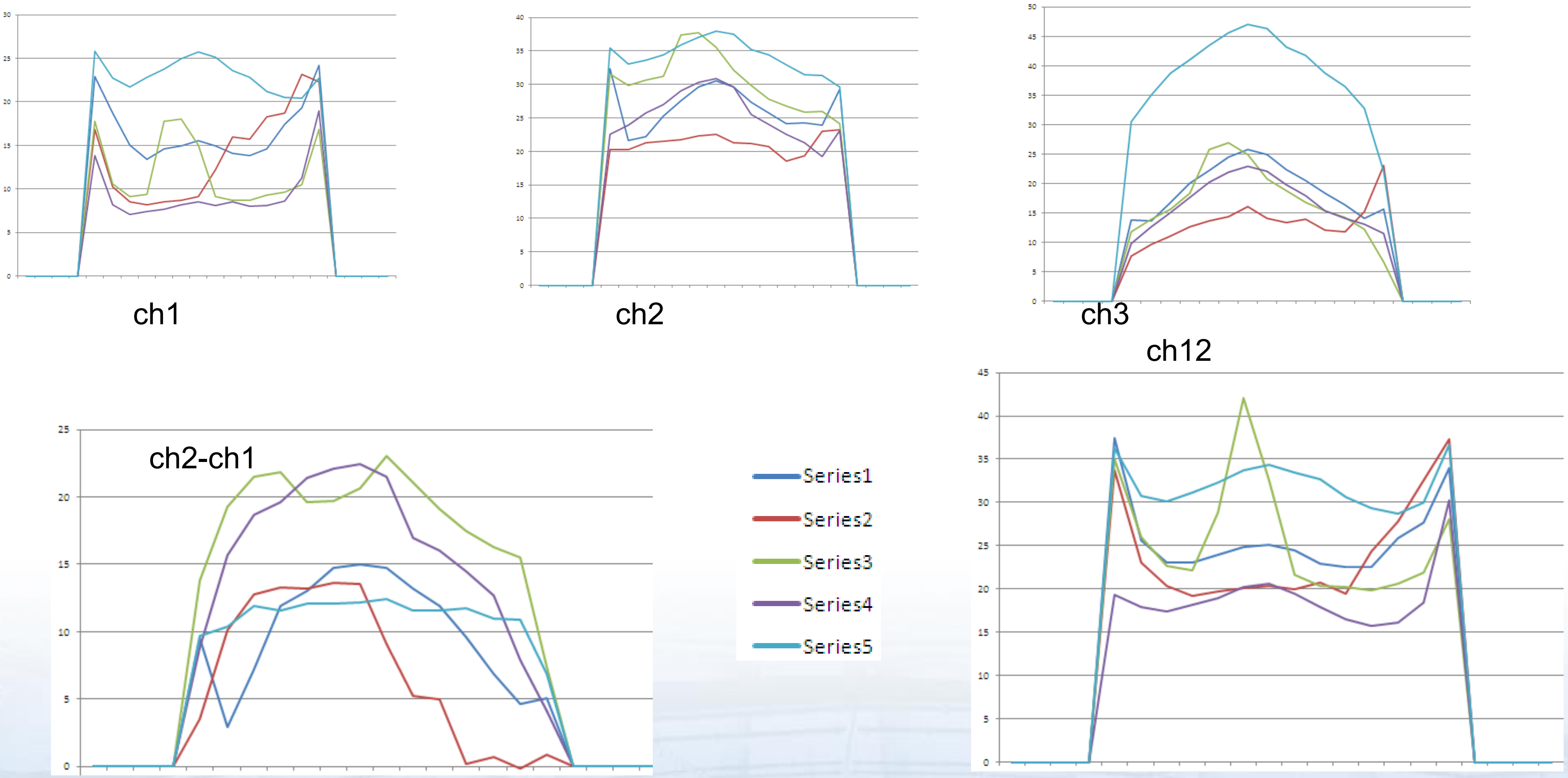
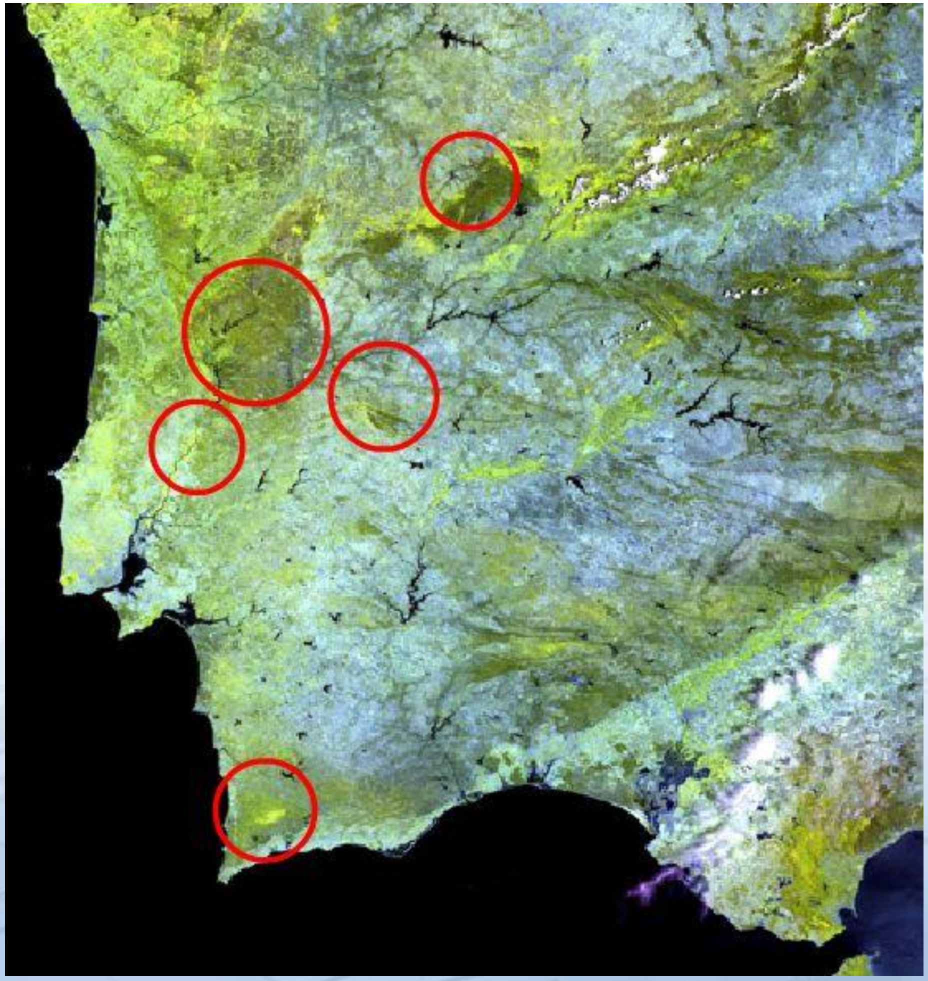
Solar reflection

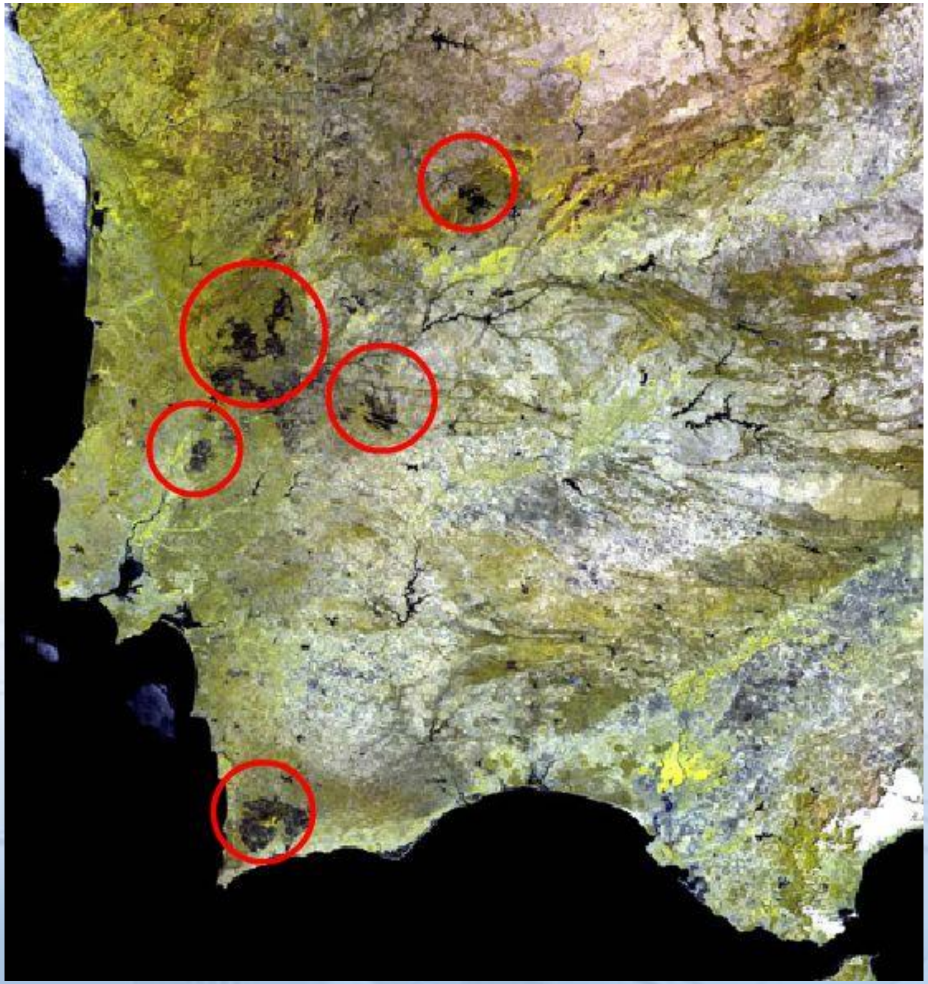


- 0.6µm reflection increases after the forest fire!
- More moderately for for 0.8µm and 1.6µm

Effect of fire on vegetation can be measured by satellite

- Fires August 2003 Portugal: 5% of portuguese territory
- Scars can be evaluated on solar channels





LAND SURFACE ANALYSIS SATELLITE APPLICATIONS FACILITY

landsaf.meteo.pt

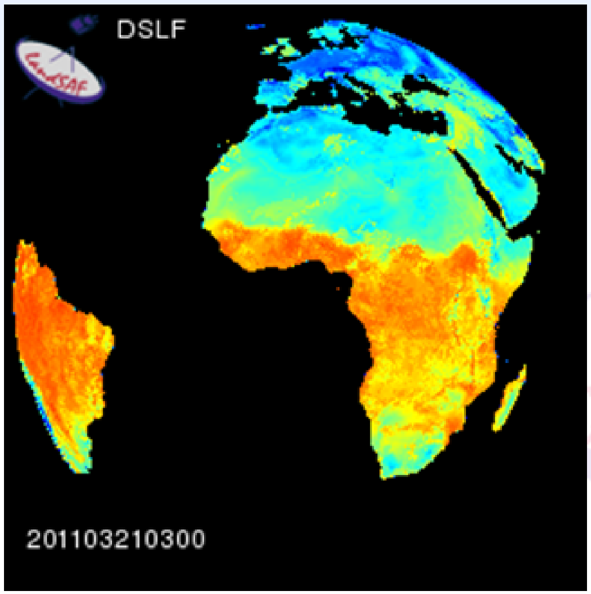
Home

The scope of Land Surface Analysis Satellite Applications Facility (LSA SAF) is to increase benefit from EUMETSAT Satellite (MSG and EPS) data related to:

- Land
- Land-Atmosphere interaction
- Biospheric Applications

The LSA SAF performs:

- R&D Programs.
- Operational Activities
  - Generation
  - Archiving
  - Dissemination



See colour legends...

of land surface related products.

Latest News:

- **Important** IM Archive system maintenance. see more...
- **Important** IM Archive system maintenance. see more...
- **Information** LSA SAF Outage see more...
- **Information** LSA SAF Outage see more...
- **Update** MSG Images see more...

Product Development Status:

MSG/SEVIRI based products

Wild Fires
- Fire Radiative Power - PIXEL
- Fire Radiative Power - GRID

Vegetation Parameters
- Fraction of Vegetation Cover
- Leaf Area Index
- Fraction of Absorbed Photosynthetic Active Radiation

Snow Cover
- Snow Cover (daily)
- Snow Cover (15 mins)

Other
- Bi-Directional Reflectance Factor
- Land Surface Emissivity

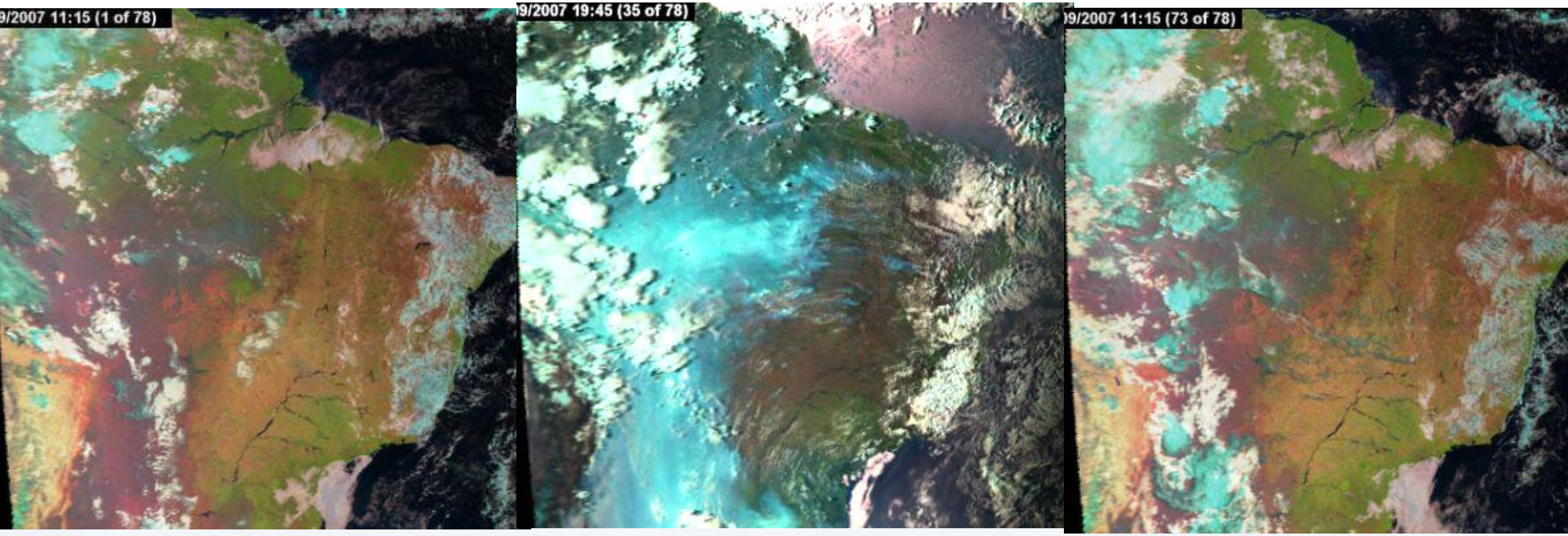
Albedo
- Surface Albedo
- MSG Ten Day Surface Albedo

Land Surface Temperature
- Land Surface Temperature (15 mins)

Down-welling Surface Fluxes
- Down-welling Surface Short-wave Radiation Flux
- Down-welling Surface Long-wave Radiation Flux
- Daily Downward Surface Shortwave Flux
- Daily Downward Surface Longwave Flux

Evapotranspiration
- Evapotranspiration (30 mins)
- Daily Evapotranspiration

Smoke

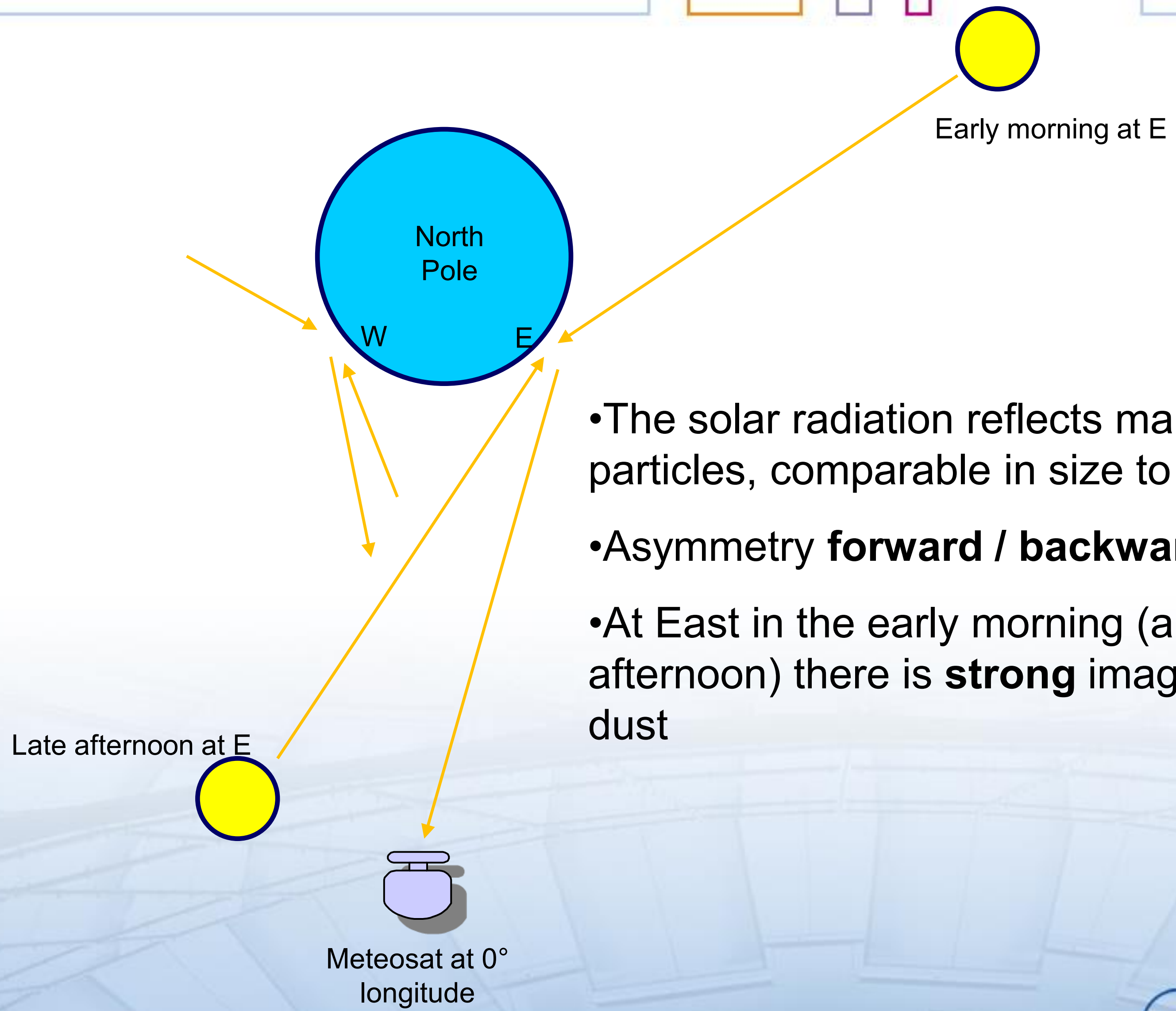


5-6 September 2007, Meteosat-9
Around sunrise and sunset times for central south America

Assuming no major smoke sink or source in 24 hours, the intensity difference is due to the sun angle

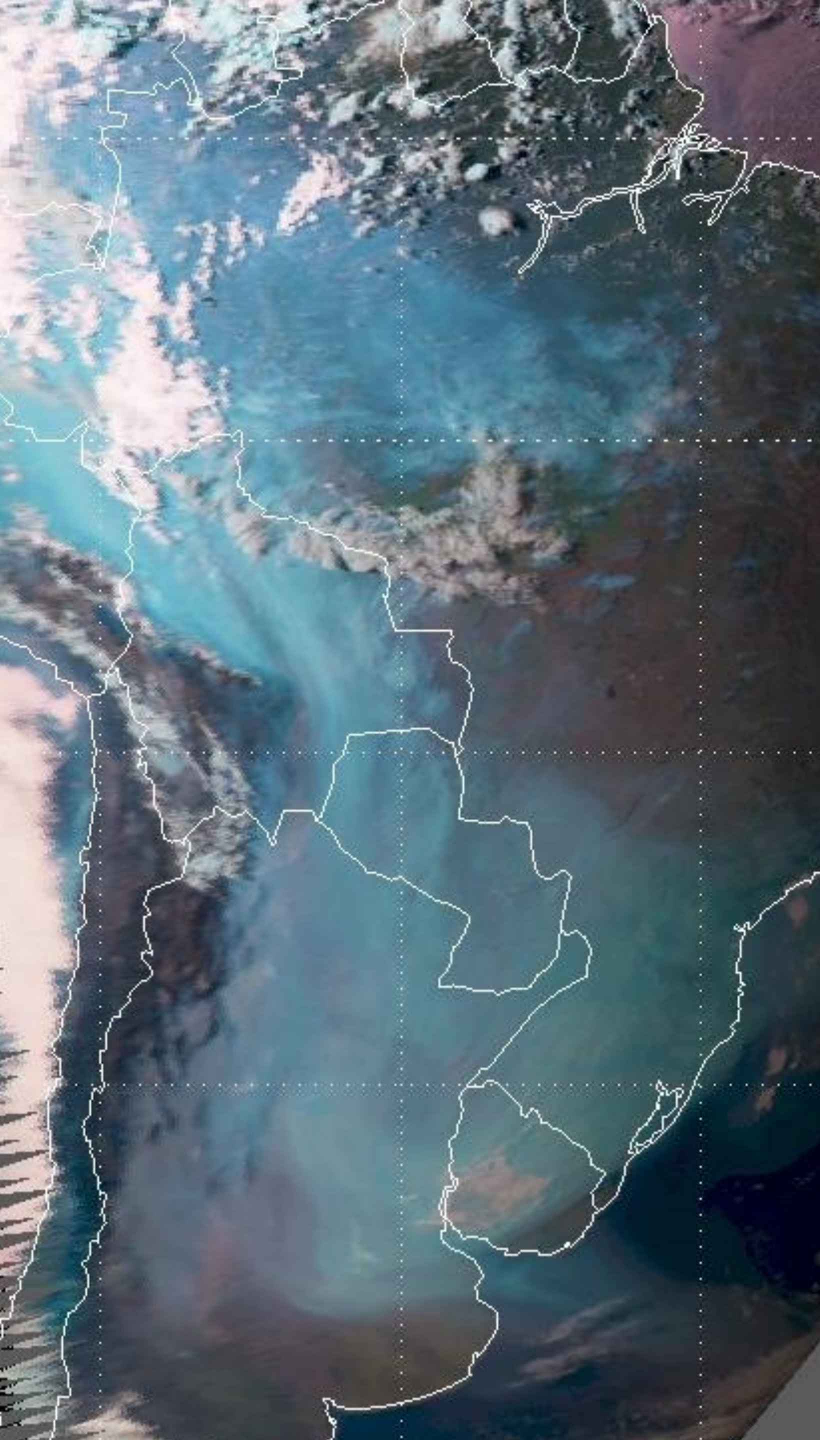
EUMETSAT

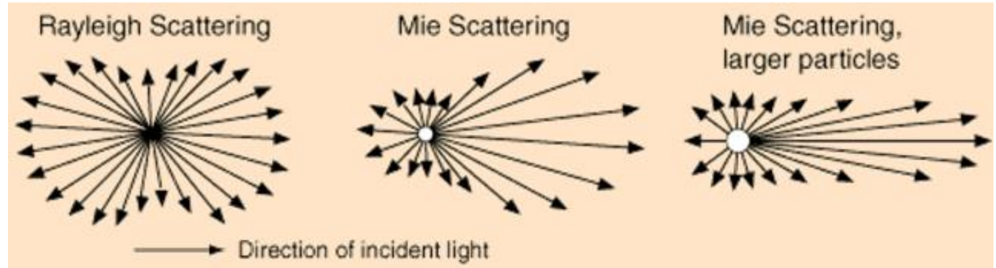
Image contrast for smoke or dust in solar images



- The solar radiation reflects mainly **forwards** on smoke particles, comparable in size to the wavelengths (Mie)
- Asymmetry **forward / backward** for a.m and p.m.
- At East in the early morning (and at West in the late afternoon) there is **strong** image contrast for smoke or dust

Meteosat9, 2010-08-21 2015 UTC



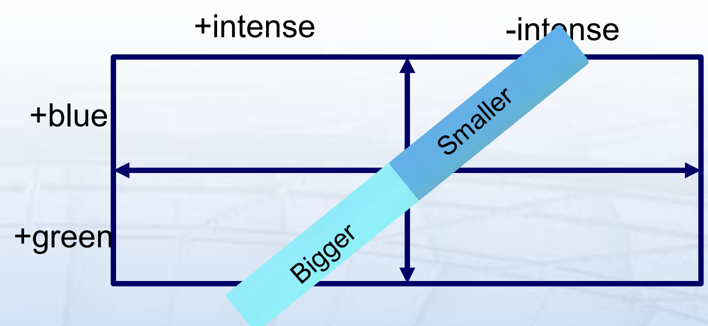


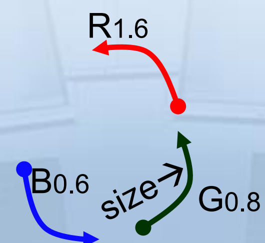
- Forward scattering favours small wavelengths (cyan)
- Bigger particles move natural RGB from blue to cyan
- Scattering intensity higher in the western late afternoon

<u>What if smoke particles were **smaller**?</u>

More intense scattering?

Greener or bluer in hue?





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Conclusions

- Meteosat Channel 3.9µm is a continuous detection tool for active fires above 100m across (1 Ha), and for measuring the burnt area as reflectivities change

- **Statistics** on fires (natural or man-made) are missing or affected by sensor saturation. An approximate retrieval can be based on frequencies below saturation

- The Land SAF offers a choice of vegetation products to assess vegetation stress and **fire risk**

THANK YOU FOR YOUR ATTENTION!

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http://training.eumetsat.int/pluginfile.php/12356/mod_resource/content/8/fire.html

- Not in Chrome!
- Eumetsat moodle, might request user name (free)

Fires brightness temperature (BT)
This applet interface describes with sliders the characteristics of the atmosphere, and provides the BT at 3.9μm (or 10.8μm with the button) for different types of soil, times of the day (sun elevation), intense and extensive fires and cloud above.
Green indicates the amount of cloud, fire and soil emissivity (bottom green square). Blue is the fraction of radiation from different sources exiting the Earth, the rest being absorbed by the Earth-atmosphere. The global value is given in upper line. The reddish square close to the Fire Temperature slider gives an idea of the extent and intensity of the fire and its size depends on the first two sliders. Its colour is given by the brightness temperature difference (fire impact) with and without the fire. Red indicates that the difference is above 5 K, so the satellite could see the fire.
The bottom table specifies the actual amounts of energy exchanged by the elements in the scene, relative to 100000 photons emitted in total by all surfaces, upwards and downwards.
Back to work:
1. First, set all sliders to 0, but "Soil emissivity" to 1 (absolutely non-reflective ground. Usually, it should be between 0.50 for desert or savannah and 0.85 for thick forest). Notice 100% of the emitted radiation reaches the satellite. This proportion will decrease when new sources are added.
2. Set the Cloud thickness to some intermediate value, and observe the changes. What do you expect for a brightness temperature, as a function of the Cloud top temperature? Are you correct? If not, why?
3. Back to Cloud thickness zero, try with Sun elevation, the sun rising over the horizon and sending radiation at 3.9μm into the atmosphere and back to the satellite. Any changes when you move the slider? How does BT vary when we change Soil emissivity on the ground?

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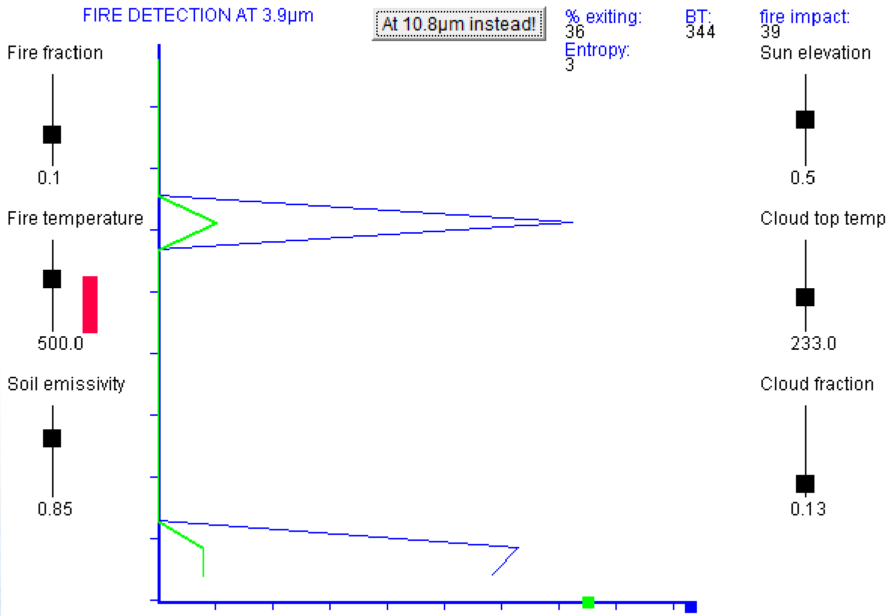
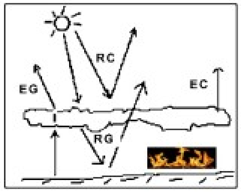
Brightness temperature at 3.9 micron for detecting fire in the pixel



	ToGround	ToFire	ToSmoke	ToCloud	ToSatel
From Ground	15	625	587	644	4370
From Fire	13548	230	1807	2081	14134
From Smoke	12163	1802	209	2419	15207
From Cloud	21	1	1	1	32
From Sun	17974	2627	2854	4299	2343



jose.prieto@eumetsat.int

Did you pay attention?

- Fire analysis from satellites is a complex matter
  - Yes
  - No
- You might confuse a fire pixel at 3.9µm with ...
  - Thin cirrus during the day
  - A water surface affected by sun glint
  - Ash particles in the atmosphere
- Smoke is better detected by solar channels when the satellite is...
  - In the backward scattering direction of sun radiation
  - In the foreward scattering direction of sun radiation
- The main obstacle to assess fire characteristics with Meteosat 3.9µm is..
  - Channel saturation at a low temperature
  - Smoke and cloud generated by the fire
  - Uncertainty on fire size
  - CO_2 generated by the fire

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